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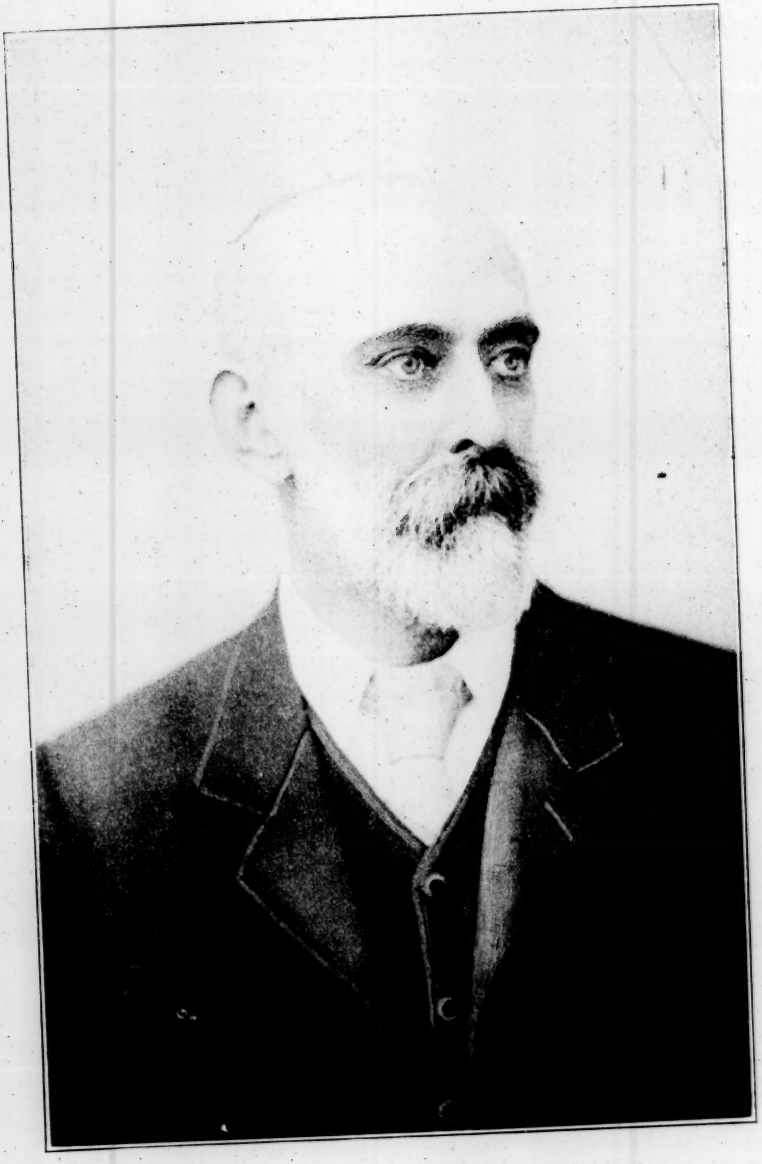

Yours faithfully
J. J. H. Teall

THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE V. VOL. VI.

No. I.—JANUARY, 1909.

ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

Jethro Justinian Harris Teall, M.A., D.Sc., F.R.S., F.G.S.,

Director of the Geological Survey of Great Britain and of the Museum of Practical Geology.

(WITH A PORTRAIT, PLATE I.)

MR. TEALL, who was born on January 5, 1849, in the Oolitic region of the Cotteswolds, at Northleach, a small market town on the Fosse Way between Cirencester and Stow-on-the-Wold, was the only child of Jethro and Mary Teall (*née* Hathaway). His father inherited some landed property in East Kent, and resided after his marriage for about two months at Sandwich, where he died in 1848 of some epidemic that was raging in the place. Mrs. Teall then returned to her relations at Northleach, where her son was born.

His early education was received at the Northleach Grammar School, and afterwards at Berkeley Villa School in Cheltenham. His first instruction in science was given by a Mr. Noteutt, a pharmaceutical chemist living at Cheltenham, who gave lectures to the boys on chemistry during the winter and on botany during the summer. Among the pleasantest recollections of his school life are these lectures, and the rambles he took over the Cotteswold Hills, where the abundance of fossil shells in the rocks excited his wonder. Otherwise much time at school was spent in trying to write Latin and Greek verses, in which he never took the slightest interest. The subject of mathematics was, however, well taught at the Cheltenham School, and fully benefiting by this, Teall was sent to Cambridge to take a Mathematical degree. With this object in view he began residence at St. John's College in the Michaelmas Term of 1869, but after a course of reading for the Mathematical Tripos he was led to attend lectures on Geology by his College Tutor, Professor T. G. Bonney, and was thereby so attracted that he devoted himself wholly to the study of Natural Science. He was fortunate also in being able to attend the last course of lectures given by the veteran Professor of Geology, Sedgwick, as well as other courses given by Professor John Morris, who acted as Deputy Professor until the appointment of Professor McKenny Hughes in 1873. A certain delicacy of constitution,

long since outgrown, obliged Teall to be non-resident during the Lent Term of 1871, but notwithstanding this he obtained a first class in the Natural Science Tripos of 1872, graduated B.A. in 1873, and proceeded to M.A. in 1876.

Teall was elected to a Fellowship of his College in 1875, which he vacated four years later on his marriage with Harriet, daughter of the late G. R. Cowen, of Nottingham.

In 1874, while still partially resident at Cambridge, he obtained the Sedgwick Prize for an essay on the Potton and Wicken Phosphatic Deposits. This was the first award of that prize, and the essay was published, with some additions, in 1875.

After taking his degree Teall was engaged for several years in lecturing on Physics, Physical Geography, Geology, and other scientific subjects under the University Extension Scheme, attracting large classes at Derby, Nottingham, and other towns in the Midland counties, in the north and west of England, and in the London district.

Ultimately Teall began to give his special attention to the microscopic structure of rocks, in which he received much encouragement from his former Tutor, and afterwards from Professor Rosenbusch.

Among his earlier contributions to petrological science were researches on the Cheviot Andesites and Porphyrites, on the North of England Dykes, and on the Whin Sill. Their publication at once gave him a high place among petrologists, and he soon increased his reputation by important papers on the metamorphism of Dolerite into Hornblende-Schist, on the Lizard Gabbros, and on the origin of certain Banded Gneisses.

In 1886 he commenced the publication, in parts, of his *magnum opus*, the *British Petrography*, a work for which he was exceptionally qualified by his knowledge of chemistry and mineralogy, his experience in field-geology, and his acquaintance with geological literature. This volume, characterized like all his work by thoroughness, embodies, in addition to the necessary summary of the researches of others, a large amount of original research and many suggestive observations; while the coloured plates of microscopic sections were far superior to any that had appeared in this country. Not only so, but unless the author had incurred serious pecuniary risk in addition to his heavy labour, the book, owing to the failure of the original publisher, would have remained incomplete. The original drawings for several of the plates were made by Mrs. Teall.

In 1888 Mr. Teall was appointed to the post of Geologist on the Geological Survey of the United Kingdom, under Sir Archibald Geikie, to take charge of the petrographical work and to deal more especially with the crystalline schists. Here it may be mentioned that this branch of the work of the Geological Survey had been initiated in earlier days by Sir Archibald Geikie, when Director in Scotland, and by J. Clifton Ward in the Lake District. It was afterwards specially attended to in the Geological Survey Office in London by Frank Rutley, who formed the first Petrographical Laboratory. On his retirement in 1882 Mr. F. W. Rudler was deputed to deal with the subject so far as his time permitted, but needless to say he could not be spared for any continuous research.

In consequence Dr. F. H. Hatch was appointed in 1886, and his attention was given mainly to the eruptive rocks.

At this time the problems connected with the age and structure of the schistose rocks of the Highlands were attracting particular attention on and off the Geological Survey, and it was of paramount importance that the field-staff should have the advice and assistance of one who would bring to their aid the precise methods of petrological science.

To quote the words of Sir Archibald Geikie—

"The duties devolving on the Petrographical Department of the Survey have increased so much in recent years, and are of such essential consequence for the field-work and the Memoirs, as well as for the Museum, that I found it necessary to apply for additional assistance. Taking advantage of Mr. Bristow's retirement, I submitted to the Department a proposal for the appointment of a trained petrographer and chemist with the rank and pay of a geologist. This proposal having been sanctioned by the Treasury, Mr. J. J. H. Teall, whose published work has placed him in the very front of English Petrography, was appointed on 20th June, 1888. I arranged that he should have charge of the determination of the schistose rocks of the Highlands, so as to be able to aid the progress of the mapping. In order to make himself acquainted with the practical difficulties encountered in the field-work, he started at once for the field and spent some weeks with the surveyors, accompanying them in their daily explorations in the various districts of the Scottish Highlands, and collecting a large series of specimens for determination in the office. His time since then has been mainly occupied in the study of these specimens, and in such rock-determinations as were from time to time required for the guidance of the mapping."[1]

From 1888 until his appointment as Director in 1901, Mr. Teall was for the most part occupied in a detailed study of the Highland rocks, but he spent a short time in mapping on the six-inch scale certain areas of Lewisian Gneiss in Rona and the northern part of Raasay. During the earlier of these years he likewise examined and reported on a considerable series of Jurassic sedimentary rocks. It was hoped that he would produce in his leisure time a companion volume to his British Petrography, and deal more fully than he had previously done with the sedimentary rocks and the crystalline schists; but this anticipation, which he himself had cherished, has unfortunately not been realized.

Dr. Hatch retired from the Geological Survey in 1892, and in the following year Mr. Teall received help in the Petrographical Department from Mr. (now Professor) W. W. Watts, who had been previously acting as petrographer on the Irish Staff. Mr. Watts resigned in 1896, and in the following year his place was filled by the appointment of Dr. William Pollard as 'Geologist' to undertake the chemical work which is inseparable from the study of petrology.

Records of the results achieved by Mr. Teall in the Petrographical Department have been given in the amplified Annual Reports of the Director General for the years 1892 to 1896, and later in the *Summary of Progress* for 1897 onwards. We read of his discovery of Riebeckite in the granophyre of Skye (1893), of a report on rocks from the Tonga Islands (1897), of his researches on Contact Metamorphism around the Ben Cruachan granite, with especial reference to the Cordierite rocks containing Corundum (1898), on the volcanic

[1] Ann. Rep. of Director General of Geol. Survey for 1888, p. 257.

rocks of the Exeter district, on a Manganese deposit at Hockworthy (1899), and on the Marbles of Assynt (1900).

On March 1, 1901, Mr. Teall was appointed Director of the Geological Survey of Great Britain and Ireland in the room of Sir A. Geikie, Director General, who retired on February 28. The change in title was probably due to the fact that the severance of the Geological Survey of Ireland was then contemplated, and it took place on April 1, 1905. Prior to this application of Home Rule to the sister country the Geological Survey underwent a thorough reorganization, under the administration of Mr. Teall. The field-work was carried on in a more systematic way in defined areas under district geologists, and it was arranged that the one-inch maps and accompanying memoirs should be published simultaneously.

The colour-printing of maps, which had been initiated in England and Wales under the direction of Sir A. Geikie, was now extended to the new Drift maps in Ireland and to the Index Map in Scotland. A very useful geological map of the British Islands on the scale of 25 miles to an inch was issued in 1906. A new series of the Index or General Map of England and Wales on the scale of an inch to 4 miles has been nearly completed, and a similar map for Scotland has been commenced. The publication of the six-inch maps of the Coalfields, long abandoned, has again been undertaken, and these maps, so important for economic purposes, are now issued both coloured and uncoloured.

The *Summary of Progress* has been somewhat modified so as to include a number of original articles and reports by various members of the Staff; and among numerous other publications it may be mentioned that the great memoir on the Geological Structure of the north-west Highlands of Scotland, promised in 1888, has at length been issued to the public, under the editorship of Sir A. Geikie. In this volume are incorporated some of the more important petrological researches carried on by Mr. Teall during the first seven years of his official service.

At the time of the reorganization new survey offices were constructed for the field-staff, with excellent rooms for the Petrographical and Chemical Departments, the former under the charge of Dr. J. S. Flett. The Museum itself was considerably modified; many manufactured articles were taken away, notably the fine collection of British pottery and porcelain, to make room for the further display of purely geological objects. In place of the Metallurgical specimens (removed to South Kensington) a fine collection of British Minerals has been arranged topographically and accompanied by a most excellent handbook prepared by Mr. Rudler. The economic applications of geology, the most important part of the official work, have been dealt with much more effectively both by the Survey and Museum. The collections of clays and building-stones have been considerably extended. The series of county memoirs on Water Supply, of which one had previously been published, has been continued, and memoirs have been issued on the Coals of South Wales and on the Oil Shales of the Lothians. Structural improvements have been made in the Museum, including the conversion of the old lecture theatre in part

into an extension of the Museum and in part into a consulting room, in connexion with the Library, where maps can be spread out and examined. Instructive geological models of the Isle of Purbeck and of Assynt have been prepared and placed in the Museum. Exhibits have also been introduced to illustrate new Geological Survey Memoirs and Maps by means of specimens and photographs from the area described. The photographic work, especially in England and Wales, has been greatly amplified.

There was a time, so we have been told, before Mr. Teall had been appointed Director, and while his attention was absorbed to a large extent by Highland schists and various altered igneous rocks, when he would not look at a fossil. As Director his attitude in this respect became greatly modified. The zonal work carried on in the Chalk by Dr. Rowe, and in Carboniferous strata by Dr. Kidston and Dr. Vaughan, stirred his enthusiasm. He has also given practical proof of his interest in palæontology by starting a series of monographs, the first of which, by Dr. Peach, on Scottish Carboniferous Schizopods, has just appeared. Although Mr. Teall was not brought up to official routine, few men could have entered with more zeal than he did upon the duties of a Director, or discharged the ofttimes arduous duties with more success in the interests of the public service and of the Geological Survey in particular, a fact to which the above remarks on the progress of the Institution sufficiently testify.

Mr. Teall, who had been elected a Fellow of the Geological Society in 1873, was chosen a Member of Council in 1884, he served as Secretary from 1893 to 1897, and was elected President in 1900. Here his firmness and courtesy, combined with his businesslike habits, made him an excellent chairman. He was also President of the Geologists' Association during the years 1898 to 1900, and President of Section C of the British Association at Nottingham in 1893. He was elected a Fellow of the Royal Society in 1890, served on the Council in 1899–1901, and was a Vice-President during the latter part of the time. He was awarded the Bigsby Medal by the Geological Society in 1889, and received their highest honour, the Wollaston Medal, in 1905. The Academy of Sciences in Paris in 1907 awarded to him the Delesse Prize for his researches in Petrography. Other marks of appreciation have been conferred in the degrees of D.Sc. Dublin 1904, Sc.D. Cambridge 1905, and D.Sc. Oxford 1908.

LIST OF SCIENTIFIC PUBLICATIONS.

A. Unofficial.

1875. "The Potton and Wicken Phosphatic Deposits": 8vo; pp. 44; Cambridge.
1879. "A Description of the Microscopic Structure of the Pitchstone from the Scuir of Eigg": Midland Nat., vol. ii, pp. 107–8.
1880. "The Pennine Chain": Geol. Mag., Dec. II, Vol. VII, pp. 92–3 and 331 (reply to Professor Hull).
"Influence of Earth Movements on the Geological Structure of the British Isles": ibid., pp. 349–57.
"A Criticism of Dr. Croll's Molecular Theory of Glacier Motion": 8vo; pp. 12; London and Nottingham.
"Origin of the Rocks and Scenery of North Wales": Midland Nat., vol. iii, pp. 214–19, 237–41, 266–9.

1883. "Notes on the Microscopic Structure of certain Specimens of Quartzite collected by Mr. W. J. Harrison, 1882": Proc. Birmingham Phil. Soc., vol. iii, pp. 194–202.
"Notes on the Cheviot Andesites and Porphyrites": Geol. Mag., Dec. II. Vol. X, pp. 100–8, 145–52, 252–62, 2 pls.
"On Hypersthene Andesite": ibid., pp. 344–8.

1884. "Petrological Notes on some North of England Dykes": Quart. Journ. Geol. Soc., vol. xl, pp. 209–47, 2 pls.
"On the Chemical and Microscopical Characters of the Whin Sill": ibid., pp. 640–57, plate.
"A Faulted Slate": Geol. Mag., Dec. III, Vol. I, pp. 1–3, plate.

1885. "The Metamorphosis of Dolerite into Hornblende-schist": Quart. Journ. Geol. Soc., vol. xli, pp. 133–44, plate.
"On some Quartz-Felsites and Augite-Granites from the Cheviot District": Geol. Mag., Dec. III, Vol. II, pp. 106–21.

1886. "Petrographical Notes on some of the Igneous Rocks of Northumberland": Proc. Geol. Assoc., vol. ix, pp. 575–81.
"Notes on some Hornblende-bearing Rocks from Inchmadampt": Geol. Mag., Dec. III, Vol. III, pp. 346–53.
"The Metamorphosis of the Lizard Gabbros": ibid., pp. 481–9, plate.

1887. "On Granite containing Andalusite from the Cheesewring, Cornwall": Min. Mag., vol. vii, p. 161.
"On the Occurrence of Rutile-needles in Clays": ibid., pp. 201–4.
"On the Origin of certain Banded Gneisses": Geol. Mag., Dec. III, Vol. IV, pp. 484–93, plate.
"The Metamorphosis of Basic Igneous Rocks": Proc. Geol. Assoc., vol. x, pp. 58–78.

1888. "British Petrography, with special reference to the Igneous Rocks," 1886–8: large 8vo: pp. 469, 47 pls.: London.
"Notes on some Minerals from the Lizard": Min. Mag., vol. viii, pp. 117–21.
"Notes on Rock-specimens collected by Mr. [Howard] Fox from the Islands off the Lizard Head": Quart. Journ. Geol. Soc., vol. xliv, pp. 314–17.

1889. "On the Amygdaloids of the Tynemouth Dyke": Geol. Mag., Dec. III. Vol. VI, pp. 481–3, plate.

1890. "Notes on some Rocks from North Pol Cornick": Trans. Roy. Geol. Soc. Cornwall, vol. xi, p. 217.
"Metamorphism in the Hartz and West of England": ibid., p. 221.

1891. (With Howard Fox.) "Picotite in Serpentine": Trans. Roy. Geol. Soc. Cornwall, vol. xi, p. 336.
"On an Eclogite from Loch Duich": Min. Mag., vol. ix, pp. 217–18.
"On a Micro-granite containing Riebeckite from Ailsa Craig": ibid., pp. 219–21.

1892. "The Sequence of Plutonic Rocks": Nat. Sci., vol. i, pp. 288–99.
(With J. R. Dakyns.) "On the Plutonic Rocks of Garabal Hill and Meall Breac": Quart. Journ. Geol. Soc., vol. xlviii, pp. 104–20, with a map.

1893. "Volcanic Rocks from the New Hebrides": Quart. Journ. Geol. Soc., vol. xlix, pp. 229–30.
(With Howard Fox.) "Notes on some Coast-sections at the Lizard": ibid., pp. 199–210.
(With Howard Fox.) "On a Radiolarian Chert from Mullion Island": ibid., pp. 211–15.
(With J. Horne.) "On Borolanite, an Igneous Rock intrusive in the Cambrian Limestone of Assynt and the Torridon Sandstone of Ross-shire": Trans. Roy. Soc. Edinburgh, vol. xxxvii, pp. 163–78, plate.
"Notes on Sections of Stonehenge Rocks belonging to Mr. W. Cunnington": Wiltshire Arch. and Nat. Hist. Mag., vol. xxvii, pp. 66–8.

1894. Presidential Address to Section C (Geology) of the British Association at Nottingham: Rep. Brit. Assoc. for 1893, p. 733.

1896. (With Sir A. Geikie.) "On the Banded Structure of some Tertiary Gabbros in the Isle of Skye": Quart. Journ. Geol. Soc., vol. [illegible] pp. 645–59, 3 pls.

"On Greenstones associated with Radiolarian Cherts": Trans. Roy. Geol Soc. Cornwall, vol. xi, p. 560.

1897. (With E. T. Newton.) "Notes on a Collection of Rocks and Fossils from Franz Josef Land, made by the Jackson-Harmsworth Expedition during 1894–6": Quart. Journ. Geol. Soc., vol. liii, pp. 477–518, plate.

(With E. T. Newton.) "Notes on a Collection of Rocks from the Tonga Islands": Geol. Mag., Dec. IV, Vol. IV, pp. 151–3.

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(With E. T. Newton.) "Additional Notes on Rocks and Fossils from Franz Josef Land": ibid., pp. 646–51.

"Petrographical Notes on Rocks from the Antarctic Regions": Proc. Roy. Soc. Edinburgh, vol. xxii, p. 66.

Part II: "Petrology: with Notes on the Microscopic Structure of the Rocks," in J. B. Harrison's Report on the Rocks of the Aruka District, British Guiana. 4to; Georgetown, Demerara.

1899. Presidential Address, "The Natural History of Cordierite and its Associates": Proc. Geol. Assoc., vol. xvi, pp. 61–74.

1900. "On Nepheline-Syenite and its Associates in the North-West of Scotland": Geol. Mag., Dec. IV, Vol. VII, pp. 385–92.

Presidential Address, "The Natural History of Phosphatic Deposits": Proc. Geol. Assoc., vol. xvi, pp. 369–87.

"The Plutonic Complex of Cnoc-na-Sroine and its Bearing on Current Hypotheses as to the Genesis of Igneous Rocks": Rep. Brit. Assoc. for 1900, pp. 750–1.

1901. Presidential Address, "The Evolution of Petrological Ideas": Quart. Journ. Geol. Soc., vol. lvii, pp. lxii–lxxxvi.

1902. Presidential Address, "The Evolution of Petrological Ideas (as regards the Sedimentary and Metamorphic Rocks)": Quart. Journ. Geol. Soc., vol. lviii, pp. lxiii–lxxviii.

"The Drift Map of the Dublin Area": Irish Nat., vol. xi, pp. 274–5.

(With T. C. Porter & J. D. Falconer.) "Volcanic Dust": Nature, vol. lxvi, pp. 130–1.

1903. "On Dedolomitization": Geol. Mag., Dec. IV, Vol. X, pp. 513–14; Rep. Brit. Assoc. for 1903, pp. 660–1.

"The Evolution of Petrological Ideas": Ann. Rep. Smithson. Inst., 1902, pp. 287–308. (Reprint of Presidential Addresses to Geol. Soc. London.)

B. Official.

(Petrological Notes contributed by Dr. Teall to Memoirs of the Geological Survey of Great Britain and Ireland.)

1. *General Memoirs.*

1893. "The Jurassic Rocks of Britain." Vol. iii: "Notes on Lias Limestones and Oolitic Ironstone," pp. 33, 302.

1894. Ibid. Vol. iv: "Petrological Notes on the Oolitic Rocks," pp. 8–12, 26–9.

1895. Ibid. Vol. v: "Microscopic Structure of Portland Beds," p. 186; "Of Purbeck Beds," pp. 233–4; "Westbury Iron-ore," p. 324.

1899. "The Silurian Rocks of Britain." Vol. i: Scotland. "The Galloway Granites and Associated Igneous Rocks," pp. 607–31. "Contact-metamorphism around the Galloway Granites," pp. 632–51.

1907. "The Geological Structure of the North-West Highlands of Scotland."

"Petrography of the Lewisian Gneiss. A. The Fundamental Complex" (written in 1894–5), pp. 42–70.

"Architectural Features of the Fundamental Complex," pp. 71–4.

B. "Rocks of presumably Sedimentary Origin in the Lewisian Gneiss," pp. 75–84.

"Pre-Torridonian Intrusive Rocks associated with the Lewisian Gneiss," pp. 85–102.

"Lewisian Gneiss of Rona and Raasay," pp. 259–61.

"Petrography of the Torridonian Formation," pp. 278–90.

"Post-Cambrian Igneous Rocks of older date than the Great Thrust-Movements of the Region: their Petrography," pp. 440–52.
"Contact Metamorphism of the Cambrian Dolomites and Limestones," pp. 453–62.
"The Eastern Schists." General Description (with J. Horne), pp. 595–601.

2. *District Memoirs.*

1897. "Geology of Cowal." General Remarks on the Petrography of the Cowal District, pp. 295–9. Description of an Albite Schist, pp. 299–300.

3. *Sheet Memoirs.*

Ireland.

1891. Sheets 31 (part) and 32 (parts of Donegal, etc.).

Scotland.

1896. Sheet 5 (part of Kirkcudbrightshire).
Sheet 75 (parts of Aberdeen, Banff, etc.).
1905. Sheet 37 (Mid-Argyll).
1907. Sheet 20 (Islay, etc.).

England and Wales.

1902. Sheet 325 (Exeter).
1904. Sheets 355 and 356 (Kingsbridge and Salcombe).
1907. Sheet 353 (Mevagissey).

II.—On Convection Currents in the Earth's Interior.

By Rev. O. Fisher, M.A., F.G.S.

IN this Magazine for November Mr. Mellard Reade referred to the difficulty of imagining the adequacy of any known force to accomplish such tremendous effects as to produce overthrusts like those which have been lately described as occurring in the North-West Highlands,[1] and he consequently appears to be a little doubtful of the reality of the phenomenon. I think, however, that the conclusion of so many competent field geologists must be accepted, and that our theories of mountain-building must be made to fit the facts rather than the facts the theories.

An overthrust is only one of the ways in which a region of the earth's crust may be compressed into a smaller area by horizontal pressures acting in opposite directions, and enormous as the stress must be, it does not seem that it need be greater to cause an overthrust than what would be required to produce the folding and consequent elevation, which is the more usual manner in which the compressing force has been satisfied; for if we suppose the mean elevation of a tract produced to be the same in the two cases, the work against gravity would be the same, and what we have to compare is, in the one case the friction along the thrust-plane, and in the other the bending and fracturing of the rigid rocks. It is not obvious that the former need require more force than the latter.

I have elsewhere endeavoured to explain the mechanism of an overthrust by the analogy of what may be observed in the behaviour of ice on a frozen river.[2] If the edge of a piece of floating ice gets

[1] Survey Memoirs, *The Geological Structure of the N.W. Highlands of Scotland*, 1907.

[2] *Physics of the Earth's Crust*, 2nd ed., p. 321.

to overlap the edge of a fixed sheet, the stream pushes the former onwards and causes an overthrust. But if an overthrust in the rocks is produced in a similar manner, we must postulate a liquid substratum, whose surface is locally moving horizontally; and if the earth is a cooling body, and if there is liquid matter in the interior, this kind of movement must needs occur. The reason of this is that the mode of cooling of a mass of liquid is by convection, the currents ascending in some places and descending in others, while the liquid flows horizontally at its surface from the ascending to the descending portions.

I am aware that at the present day (at least in Britain) a belief in the liquidity of the earth's interior is heresy. The orthodox opinion appears to be that it is neither liquid nor solid, but both at once, and so we run with the hare and hunt with the hounds. But such a state of affairs would not admit of convection currents.

I will briefly mention some phenomena which appear to be explicable on the hypothesis of a liquid substratum holding water-gas in solution and cooling by convection—

(1) Obviously volcanic action stands first, where we see frequent ebullitions of fresh lava, varying in character from one eruption to another, and building up great mountains as if supplied from an inexhaustible reservoir below.

(2) The same agency, viz. horizontal flow, which, as above suggested, might cause compression to be satisfied with an overthrust, would also account for other forms of compression, such as are more usually characteristic of mountain ranges.

As to whether the friction of a flow of the substratum would be adequate to supply the force which has compressed the crust in mountain ranges, we may again refer to the analogy of ice. Nansen found that in the Polar regions the thickness of the ice under direct freezing does not usually exceed 4 metres. But it becomes very much thicker by the piling up of broken ice-sheets, driven together and mounting one above another, and he says that the pressure is largely dependent upon the tidal current, especially at the margin of the ice-field.[1] Now the ratio of the densities of the crust and substratum is probably very close to that of ice and water, so that a similar action of currents in the two cases would be likely to produce similar effects of compression.

(3) Variations of level, especially such as have been described by Professor Hull and Dr. Spencer, appear to be most readily accounted for by convection currents, the surface rising over upward and sinking over downward currents, as I have endeavoured to explain elsewhere.[2]

(4) Another phenomenon which may possibly be due to convection currents is the irregularity in the small changes of latitude which arise from slight variations in the position of the axis of rotation within the earth. Mathematicians tell us that the anomalies of these movements can be explained by elasticity. But it seems that, although elasticity might modify the period of a regular movement of the pole of

[1] *Nature*, February 11, 1897. [2] American Journal of Science, 1900.

rotation around its mean position, it would not explain the remarkable irregularity both in amplitude and period with which its wanderings are affected.[1] Professor Milne is of opinion that some connection exists between these irregularities and the frequency of large earthquakes.[2] Might not convection currents, by slightly altering the distribution of mass within the earth in an irregular manner, account for these irregular wanderings of the pole?

(5) Observations upon the force of gravity in India have revealed the remarkable result that changes appear to have taken place within the last thirty years. At Dehra Dun, at the foot of the Himalayas, there has been found a notable increase of gravity corresponding to four swings of the second's pendulum in twenty-four hours.[3] If the two sets of observations that show this are to be depended on, we have here an absolute proof that there has been a change of density and consequently movement in the substratum of that neighbourhood, and it is noticeable that, in the interval between the two dates, a severe earthquake was experienced at that place.

(6) Making use of the best data newly available, I have calculated by a mathematical method that, on the hypothesis that the crust of the earth is being formed by congelation out of a liquid subjacent magma, the age of the world would not be greater than about eight million years unless there are convection currents in the interior. Dr. See, Professor of Mathematics to the U.S.A. Navy, has accepted my calculation, and also the conclusion at which I have arrived regarding the corresponding age of the world, and, not believing in the existence of convection currents, he has been led to argue that geological phenomena do not require a longer period for their accomplishment than about eight million years.[4] Few geologists, I think, will be willing to accept so short a time. It follows that we have the opinion of an accomplished mathematician to endorse the result of my calculations, which, on any reasonable estimate of the world's age, go far to prove the existence of convection currents.

The two principal objections to the hypothesis of a liquid interior appear to be (1) the existence of a fortnightly tide, and (2) the two phases of the preliminary tremors of a world-shaking earthquake. The argument for rigidity from the fortnightly tide is so extremely technical and refined that it is not for the ordinary geologist to follow it.[6] It is based on the average of observations taken in India, Britain, and France;[7] but, confining our attention to India, it seems doubtful whether that tide can be detected.[8]

The argument for rigidity from the different velocities of the two phases of the preliminary tremors of an earthquake assumes that

[1] *Nature*, February 27, 1896, also May 12, 1898.
[2] British Association Report, 1903 and 1906.
[3] Colonel Burrard, Phil. Trans., vol. clv, A 394, p. 294.
[4] *Physics of the Earth's Crust*, 2nd ed., Appendix, ch. xxvii.
[5] Proc. American Phil. Soc., 1907, vol. xlvi, p. 221.
[6] Thomson & Tait's *Natural Philosophy*, 1883, pt. ii, p. 142.
[7] Knott's *Physics of Earthquakes*, p. 164.
[8] *Physics of the Earth's Crust*, Appendix to 2nd ed., p. 31.

the second phase is propagated as a distortional wave, for, "among material bodies, a solid alone really possesses the rigidity sufficient for the production within it of transverse vibrations and for their maintenance during their propagation."[1] But I have suggested an alternative explanation of the two phases, depending upon the presence of water-gas in the magma, which, from volcanic eruptions, we know to be a constituent.[2]

The cause usually assigned for the supposed rigidity of the interior is the enormous pressure to which it is exposed. It is held that this would so increase the viscosity as to render it practically solid, but I am not aware that any experimental fact has shown this to be probable; for it is a different question from that of the melting temperature being raised by pressure. We know that in the case of a vapour there is a certain critical temperature, above which no pressure will reconvert it into a liquid. Is it not possible that in the case of a liquid there may be a critical temperature above which no pressure will convert the liquid into a solid? And this may be the case in the earth's interior.

III.—On the Affinities of the Triassic Plant *Yuccites vogesiacus*, Schimper & Mougeot.

By E. A. Newell Arber, M.A., F.L.S., F.G.S., Trinity College, Cambridge; University Demonstrator in Palæobotany.

In a paper published in 1907, in the Transactions of the Linnean Society of London,[3] I described and figured, under the name *Zamites grandis*, sp. nov., some excellent specimens of detached leaves recently collected by my friend Mr. L. J. Wills, B.A., F.G.S., from the Keuper rocks of Bromsgrove (Worcestershire).

These fossils were regarded as identical with the specimens from the Bunter of the Vosges, first described by Schimper & Mougeot[4] under the name of *Yuccites vogesiacus*.

In discussing the affinities of this plant I pointed out[5] that this question had been "a subject of much confusion in the past, and the cause of considerable difficulty at the present". The difficulty lay in the fact that these large, lanceolate, Monocotyledonous-looking leaves, with close, stout, and strictly parallel nerves, were almost invariably detached, and with one possible exception, which, however, was not very conclusive, there was no direct evidence, either from the British or the Continental examples, as to the manner in which they were borne. Consequently direct evidence as to their affinities was lacking.

On the other hand, these leaves presented a very close resemblance to the pinnæ of a Zamitean frond except in size, in which respect they were very dissimilar. I concluded, however, that they were the detached pinnæ of a Zamitean frond of large size.

[1] Poincaré, *The New Physics*: International Scientific Series, 1907, vol. xc, p. 173.
[2] Proc. Cambridge Phil. Soc.
[3] Arber, Trans. Linn. Soc. London, 1907, ser. II, Bot., vol. vii, pt. viii, p. 109.
[4] Schimper & Mougeot, Monogr. Plant. foss. Vosges, 1844, p. 42, pl. xxi, figs. 1 and 2.
[5] Arber, ibid., p. 115.

In this conclusion I was in agreement with Professor Seward, who had recently attributed to the same genus some very similar fossils from the Stonesfield Slate of Oxfordshire, which he described under the name *Zamites megaphyllus* (Phillips).[1] In referring Schimper & Mougeot's specimens from the Bunter, and the examples collected from the English Keuper, to this genus, it was found necessary, for reasons fully explained in my former paper,[2] to change also the specific name, and the term *Zamites grandis*, sp. nov., was instituted for their reception.

Quite recently, however, Mr. Wills has brought to light a further specimen from Bromsgrove, of great interest as showing the bases of several leaves still attached to an axis. From this example there appears to be no doubt that these fossils were not the detached leaflets of a pinnate frond of Cycadophytean affinity, but *leaves spirally arranged on a stem or shoot*.

This exceptional specimen will be fully described by Mr. Wills in his forthcoming memoir on the Keuper rocks of Bromsgrove. It may suffice to state that it shows a flattened axis, some 8 cm. long, on which portions of some nine leaves are seen spirally arranged, their bases, in three or four instances, being in continuity with the stem or branch.

It is, however, proposed to discuss here the affinities of this fossil, which can no longer be regarded as a member of the Cycadophyta.

In the first place, it is unfortunate that this recent discovery, while of great interest, hardly sheds any definite light on the question of affinity. The fructification of this plant is still unknown, and, until it has been correlated with the leafy shoot, all conclusions must, at the best, be of a provisional nature. As compared with Upper Palæozoic plants, the Bunter and Keuper fossils recall very vividly the leaves of *Cordaites*. Compter,[3] in describing similar, if not identical, specimens from the Lower Keuper of East Thüringia, attributed them to this genus under the name *Cordaites keuperianus*, sp. nov. Zeiller [4] has supported this conclusion, and has drawn attention to the fact that the occurrence of *Artisia* (*Sternbergia*)-like pith-casts in the Lias, as recorded by Lignier,[5] lends probability to this view. Further support is also afforded by the reflection that if the Bromsgrove specimens had been obtained from Palæozoic rocks they would undoubtedly have been referred to the genus *Cordaites*.

On the other hand, it is now apparent that plants of similar habit to those under discussion from the Bunter and Keuper are not uncommon in the Mesozoic rocks. I have recently examined, by the kindness of Professor Sollas, one of the type-specimens[6] from the Stonesfield Slate of *Zamites megaphyllus* (Phillips), refigured by Professor Seward,[7] in which some of the leaves are still attached to

[1] See Arber, ibid., p. 117. [2] See Arber, ibid., p. 115.

[3] Compter, Zeitsch. Naturwiss. Leipzig, 1894, vol. lxvii (ser. v, vol. v), p. 22[illegible], pl. iv, fig. 9.

[4] Zeiller, *Elém. de Paléobotanique*, 1900, p. 213.

[5] Lignier, Mém. Soc. Linn. Normandie, 1895, vol. xviii, p. 135, pl. vii, fig. [illegible].

[6] No. $\frac{\text{MM}}{748}$ in the Oxford University Museum.

[7] Seward, *Jurassic Flora*, vol. ii (Brit. Mus. Cat.), 1904, p. 114, text-fig. 11.

the axis. In the light of Mr. Wills' new discovery, I am now of opinion that the mode of attachment here, though not very clearly seen, is probably spiral, and that we are not dealing in this case with a pinnate frond.

Other fossils of a similar type are to be found in the Cretaceous *Krannera mirabilis* of Velenovský and the *Eolirion* (*Elolirion*) *primigenium* of Schenk.[1] The latter strongly recalls the Bromsgrove specimens, and in Schenk's example the leaves are obviously attached spirally to an axis or shoot, with which many of them appear to be in continuity. We have, therefore, a family of plants including the genera *Yuccites*, Schimp. & Moug., *Palæozamia*, Phillips, *Krannera*, Vel., and *Eolirion*, Schenk, existing in both Triassic, Jurassic, and Wealden times, with large Monocotyledonous-like leaves, spirally arranged on the shoot. The question is, are these fossils best regarded as Monocotyledons, or as members of the Cordaitales or Coniferales, or again as a distinct family possibly intermediate between the Cordaitales and Coniferales? For a complete answer we must wait until the fructification is known. At present the balance of probability does not appear to me to lie more in one direction than in another, if we exclude the possible attribution to the Monocotyledons, which, on general grounds, is by far the least probable. It is generally agreed that Monocotyledons did not exist before Lower Cretaceous times, and that the earliest remains of this group come from rocks of slightly more recent age than the British Wealden.

With regard to the possible Cordaitean affinity, there is much to be said in its favour, as Zeiller[2] has already pointed out. The fact that no *Artisia*-like casts have been collected from the Keuper of Bromsgrove is hardly trustworthy evidence, either for or against the argument. They are already known from a higher horizon, and negative evidence is rarely reliable if unsupported by other data. If the attribution to the Cordaitales proves to be correct, then this group must have been most remarkable in regard to its long persistence in geological time. It occurs in the Lower Carboniferous, if not in the Devonian, and in Upper Carboniferous and Permian times it formed one of the dominant elements of the flora. The argument that, because most of the great dominant Palæozoic groups had either died out, or sunk to the position of subsidiary or insignificant factors in the flora by the time we reach the Rhætic, the Cordaitales were unlikely to have persisted throughout Mesozoic times, is not, however, in itself conclusive, if unsupported. The Leptosporangiate Ferns, for instance, have maintained their place as dominant elements in the flora throughout the Mesozoic and Tertiary periods even to the present day.

Yet in the absence of any knowledge of the fructification I hesitate to accept this view even provisionally. It is possible that the fructifications of these Mesozoic plants may prove to be more nearly related to the Coniferales than to the Cordaitales, or even occupy an intermediate position between the two. The theory that

[1] Schenk, *Palæontogr.*, 1869, vol. xix, Lief. i, p. 20, pl. vii fig. 4.

[2] Zeiller, ibid., pp. 212–13.

the Coniferales themselves sprang from the Cordaitales, which is widely but not universally accepted as a working hypothesis, would then receive strong support, and the Cordaitean-like leaves would be easily explained. Even in some modern Araucariæ, such as *Agathis* (*Dammara*) *loranthifolia*, Sal., the leaves also to some extent recall those of a modern Monocotyledon, and are not entirely dissimilar to those of *Cordaites*.

I am thus inclined to regard the question of the affinities of this family of Mesozoic plants as an entirely open one until the fructification is discovered. At the same time I think it probable that the fructification will be found eventually to have departed somewhat from the type characteristic of the Cordaitales.

There remains the discussion of the name by which these Bunter and Keuper fossils should be known. Unless we adopt the attribution to *Cordaites* outright, which seems to me to be hardly justifiable, and if we regard the affinities of this plant as still wholly obscure, there seems to be no better course than to fall back on the original name *Yuccites vogesiacus* of Schimper & Mougeot, as a temporary and provisional expedient until more information is available. At present the genus *Yuccites* does not appear to have any established position. The name is of course open to the grave objection that it suggests affinity with the Monocotyledons, to which group, as also in the case of *Eolirion*, it was originally referred. Yet, on the other hand, there do not appear to be any species of *Yuccites* known beyond doubt to belong to the Monocotyledons, and the invention of a new genus, whether implying affinity to the Cordaitales on the one hand or to the Coniferales on the other, does not appear to me to be advisable on the present evidence. I propose, therefore, to retain temporarily the name *Yuccites vogesiacus*, Schimp. & Moug., for these specimens from the Bunter of the Vosges and the Keuper of Bromsgrove.[1]

IV.—*Limulus Woodwardi*, sp. nov., from the Lower Oolite of England.

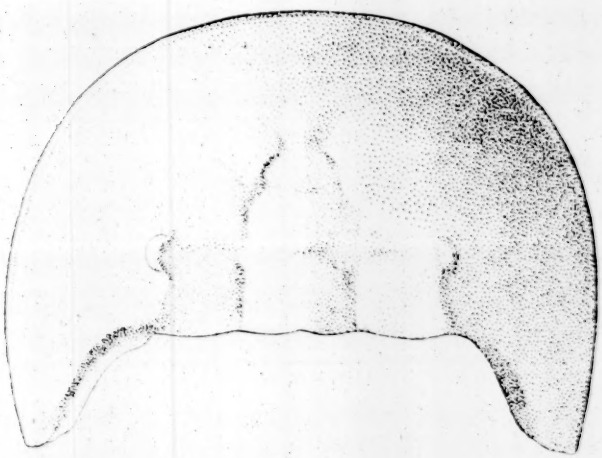
By D. M. S. Watson, B.Sc., Beyer Fellow of the Victoria University of Manchester.

MY friend Mr. F. H. Gravely during September, 1908, obtained from the ruins of an old wall at Doddington, near Wellingborough in Northamptonshire, the carapace of an Arthropod, the value of

[1] I take this opportunity of correcting two slips which appeared on p. 110, paragraphs 2 and 3, of my previous paper with regard to the horizons on which some of the earlier Cycadophytean fronds occur in the Palæozoic rocks. I am indebted to Professor Zeiller for calling my attention to these errors. The oldest known specimens of *Zamites*, *Plagiozamites*, and *Pterophyllum* should there be stated to be derived from the Stephanian, and not from the Westphalian. Similarly, the beds in the Vosges from which *Plagiozamites* was obtained are of Permian age, and not Westphalian as stated. Professor Zeiller also informs me that the fossil recorded by Zalessky as *Plagiozamites* from Manchuria has proved to be a *Rhacopteris*. Professor Zeiller, in his "Bassin Houiller et Permien de Blanzy et du Creusot", a memoir which I did not see until after my paper had appeared, includes the *Zamites Planchardi* of the Commentry Flora in the genus *Plagiozamites*. Consequently the genus *Zamites* is as yet unknown from the Palæozoic rocks; and it is doubtful if any typical representatives have been described of earlier age than the Rhætic.

which he at once recognized. This specimen he has now presented to the Manchester Museum, and by his kindness I am enabled to offer a short description of it here.

The fossil consists of an iron-stained cast of the dorsal surface of a carapace, the left side of which had suffered considerable abrasion before the specimen was collected. The matrix is a grey, fine-grained sandstone, somewhat calcareous, and containing small Pelecypods and apparently some oolitic grains. I do not know any rock exactly like it from any other locality, but it considerably resembles some types of the Northampton sand to which it almost certainly belongs, as most walls in the neighbourhood are built with rocks belonging to that formation. Despite this uncertainty as to the exact horizon of the specimen, it seems to me worth description as being the only known example of a Mesozoic Merostome in Britain.



Cephalic shield or carapace of *Limulus Woodwardi*, Watson, sp. nov. Natural size. From the Inferior Oolite (?) of Doddington, Northamptonshire.

The anterior edge of the carapace is smooth and forms a large arc of a circle, considerably more than 180°.

The posterior edge of the carapace is bounded by three distinct lines; these are a central, nearly straight edge, to which the abdomen was attached. This attachment is about half the entire width of the carapace, and is considerably in advance of the genal angles. From the ends of this line two other edges curve out in gentle ogees to the genal angles. These angles are not produced, but end in blunt spines. The edge of the carapace along these lateral portions is curved downwards, forming a groove.

The carapace bears the following marks:—In the centre, starting from the back, is a distinct area—the glabella—separated by grooves from the general surface. These bounding grooves approach each

other anteriorly, and then rather suddenly separate before quite touching; they then shortly die out. The glabella is divided transversely by two grooves, one a little behind the point of minimum width, the other half-way between that and the back of the carapace.

In the same line as this last groove are the lateral eyes. They are situated about three times the width of the glabella apart and stand up above the general level, just as in *Limulus Polyphemus*. Their structure cannot be seen.

On the right side is a trace of a small projection continuing the line of the eye ridge at the extreme back of the carapace. The carapace is strongly arched from side to side and is quite unerushed.

The measurements are as follows:—

	cm.
Width between genal angles	7·64
Greatest width	8·1
Length on median line	4·2
Width on glabella at back	1·5
Width of attachment of abdomen	4·2
Distance of eye in front of line of attachment of abdomen	1·1
Distance apart of lateral eyes	1·2
Depth of carapace at back	1·8

There can be no doubt that the carapace described above is that of a *Limulus*. Its resemblances to the recent *L. Polyphemus* are extremely striking, the differences being slight variations in certain proportions.

In *L. Polyphemus* the carapace is longer than wide, and the articulation of the abdominal dorsal shield is wider than in the British form. The lateral eyes are placed somewhat further forward, and the glabella is not so obviously divided by transverse grooves.

The British specimen differs considerably from *L. Walchi*, the species which occurs in considerable abundance in the Solenhofen Slate; in *L. Walchi* the glabella is not divided by transverse grooves, and the lateral eyes are apparently not mounted on a distinct projection as they are in the new species. On the other hand, the upper oolitic species has the same downturned edge of the lateral parts of the posterior edge which is such a feature of the Northamptonshire species. *L. syriacus* from the Cretaceous of Hakel, Syria, differs greatly in the general shape of the carapace and in the crimping of the very narrow glabella.

There remain only *Limulus Decheni* from the Oligocene of Tenchern near Merseborg, which is a large species; two small and simple species from the Trias of Germany, and one from the European Rhætic. These last are forms with a simple carapace of small size. It thus appears that the Doddington specimen is distinct from all known species, and I suggest that it be called *Limulus Woodwardi* after Dr. Henry Woodward, to whom our knowledge of the British Merostomes is so largely due.

V.—Note on the Igneous Rocks of Singapore, with special reference to the Granite and Associated Rocks carrying Rhombic Pyroxene.

By J. B. Scrivenor, F.G.S., Geologist to the Federated Malay States Government, and formerly of H.M. Geological Survey of Great Britain.

In a former paper[1] the writer endeavoured to show the connection between the sedimentary rocks of Singapore and certain rocks in Pahang. On the occasions when opportunities for geological work in Singapore have presented themselves numerous specimens of igneous rocks have been collected, and it is the purpose of the present paper to describe briefly the observations recorded. It is hoped that this will give some further idea of the geology of the island of Singapore; but apart from a general description the pyroxene-bearing rocks associated with the granite appear to the writer to require a note as being of exceptional petrological interest.

The island of Singapore is composed, as far as is known at present, of a series of estuarine rocks, which are a continuation of the Tembeling Series in Pahang, granite, with associated rocks to be described later, and some other igneous rocks, most of which are referred to an extensive series of volcanic rocks in Pahang associated with Permo-Carboniferous beds. The estuarine series may be referred to the Upper Gondwana on the one hand, while on the other it is probably represented by some of the West Borneo Beds described by Mr. Wing Easton.

The granite is certainly later than the sedimentary rocks, which are, in some parts of the island, highly disturbed; therefore it may be assumed that the granite is at any rate post-Triassic, perhaps post-Inferior Oolite. In the peninsula the writer's observations have led him to believe that there are two types of granite which may be of different age, a porphyritic and a non-porphyritic type. As pointed out before, however, "against a difference in age may be urged the fact that both facies are connected with deposits of tin-ore, and also that beyond areas of gneiss, produced apparently by movements in the partially solidified magma, no evidence has been found of disturbances on a large scale affecting either." The Singapore granite belongs to the non-porphyritic facies.

Mr. R. B. Newton[2] gives a list of the early literature dealing with Singapore in his "Notes on Literature bearing on the Geology of the Malay Peninsula, etc.". Logan[3] says that in Bukit Timah "solid greenish granite and syenite, passing in some places into compact laminated felspar", are seen, while on Pulau Ubin are "various forms of granite and syenite (often approaching and sometimes passing into greenstone)", and hornblende occurs, both on Pulau Ubin and elsewhere.

Rocks of the Pahang Volcanic Series.—None of these rocks have

[1] Geol. Mag., 1908, pp. 289–91. The map with this paper will serve to show the position of Pulau Ubin in Changi.

[2] Geol. Mag., 1901, pp. 128–34.

[3] J. R. Logan, "Notices of the Geology of the Straits of Singapore" (with geological map): Q.J.G.S., 1851, vol. vii, p. 310.

been seen *in situ*. They are the only evidence at present of pre-Triassic rocks in the island. Close to the Ballestier Road, and not far from the junction with the Thomson Road, small boulders were found exposed on the site for a hospital. These consist of trachyte. At the corner of Grange and Orchard Roads small boulders of andesitic tuffs were found, similar to the tuffs in Pahang.

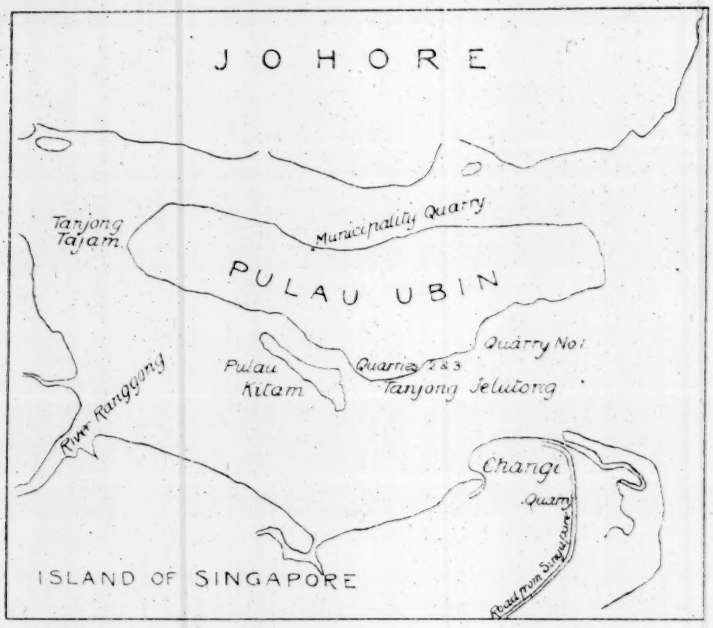


Fig. 1.—Sketch-map showing Pulau Ubin and Changi, Singapore.

Rocks of Doubtful Position: Quartz Porphyry.—At Pulau Pergam, in the Straits of Johore, is a mass of 'core-boulders', i.e. hard unweathered cores left from the denudation of a bed or mass which once occupied approximately the same site, lying on the same rock *in situ*. It consists of blebs of quartz and crystals of orthoclase, with some of plagioclase and microperthite, crowded together in a green chloritic base. A little biotite occurs, and in one slide flow-structure was seen. This quartz porphyry may belong to the same period of eruption as certain masses of quartz porphyry in the Federated Malay States connected with the granite, or it may be referred to certain masses of quartz porphyry that occur isolated from other igneous rocks. The data are too few to speak with anything approaching certainty.

Ophitic Dolerite or Diabase.—On the hospital site near the Ballestier Road the writer found two boulders of an altered ophitic rock with pale-green secondary amphibole, epidote, and masses of minute flakes of biotite. The rock recalls certain diabases in the

peninsula; but, like them, cannot yet be assigned to any particular group. At the corner of Grange and Orchard Roads again, boulders of a less altered ophitic rock were found containing violet augite, olivine, calcite, and plagioclase. Dolerite dykes are known to traverse the granite in the Peninsula; therefore it is quite probable that these boulders were derived from similar dykes in Singapore. On the other hand, they may be remnants of basic lavas of the Pahang Volcanic Series.

The Granite.—In the Federated Malay States granite immediately suggests the possibility of the occurrence of tin-ore, and it would appear that at one time tin-ore was worked in Singapore, because the name "Bukit Timah", which is given to a granite hill in the interior of the island, signifies the "Tin Hill". The writer is not aware of any records of tin-working there, however, and no traces of cassiterite, or indeed of any of the granite modifications which may generally be taken as guide to tin deposits, were discovered. But at Bukit Panjang, farther to the north, the writer found a small pocket of cassiterite, molybdenite, chlorite, and calcite in the granite. The weight of the cassiterite is considerably under a gram; therefore the first recorded occurrence of tin-ore in Singapore cannot be said to be encouraging from a commercial point of view. The normal granite is a medium-grained, non-porphyritic rock, with biotite and varying amounts of green hornblende. Sometimes the biotite occurs alone. A considerable proportion of the felspar is plagioclase.

At Bukit Timah the granite contains comparatively little biotite, and was found in one place to pass into a rock consisting of crystals of orthoclase, and quartz generally showing crystal outline, together with a biotite, in a ground-mass of even-grained mosaic of quartz and felspar.

At Changi the granite contains more hornblende than biotite, and in this hornblende-granite was found a vein of rock strongly resembling, in a hand-specimen, a tourmaline bearing modification of granite. Under the microscope, however, it proved to consist of quartz grains and poorly formed crystals of orthoclase, with irregular masses of dark-green hornblende.

On Pulau Ubin the normal type of granite is predominant. It is worked in large quarries along the coast of the island. The most interesting specimens collected on Pulau Ubin, however, are certain pyroxene-bearing rocks which require more detailed description. They were found in the Municipality Quarry on the north of the island.

Slides from a piece of the ordinary granite in this quarry do not show anything of particular interest. The proportion of ferromagnesian minerals (biotite and hornblende) and iron-ores is not large. One specimen (*a*) was collected, however, that is much darker than this granite. In the hand-specimen the felspar appears fresh, and the quartz cannot be distinguished with certainty. Biotite is plainly visible. Sections show that quartz is not very abundant, and that there is more plagioclase than orthoclase. The ferromagnesian minerals are biotite, fibrous amphibole, and rhombic pyroxene. The three are as a rule closely associated, and there is good reason to

suppose that the amphibole has been derived from rhombic pyroxene. When the three minerals occur clustered together they are generally accompanied by a considerable quantity of iron-ore.

The rhombic pyroxene rarely shows good crystal outline, and then only in the case of basal sections. The outline of the longitudinal sections is generally rough, but the straight extinction can be plainly seen parallel to the long axis of the sections and the cleavage. In thin section the mineral is colourless or almost so. In sections slightly thicker than the usual rock slide, however, and in grains from the crushed rock, it appears coloured and gives a pale-green and pale-orange pleochroism. The colour is faint, and the mineral must be considered as being much nearer enstatite than hypersthene.

Fig. 2.—Dyke-like mass of enstatite-vogesite in the hornblende-granite of Pulau Ubin, Singapore. (From a photograph.)

Another specimen (*b*) was finer in grain than the last, and contains the same minerals. The amount of quartz present is small.

In the same quarry a big vein of a still finer-grained, dark reddish brown rock (*c*) was seen standing out from the working face, where the granite was being worked away on either side of it like a dyke, and the same rock occurred close by mingled with the granite in such

a way that it was impossible, viewing this mass alone, to tell which rock was the later.

This rock proved very interesting in section. There are three ferromagnesian minerals in a clear base consisting of small grains of orthoclase, quartz, and a little plagioclase. They are biotite (the least abundant), brownish-green hornblende in ragged flakes (abundant), and numerous granules and ragged prisms of rhombic pyroxene, showing the same pale-green and pale-carmine pleochroism as the mineral in the rocks described above.

Traversing this dark reddish brown rock the writer found a small white and pale-brown vein, which on examination proved to consist of grains of pink garnet, pale-green monoclinic pyroxene, wollastonite (largely altered to calcite), and a little quartz.

At Changi large masses of a fine-grained rock (*d*) were found in the granite resembling the reddish-brown rock from Pulau Ubin, but under the microscope the resemblance proves to be deceptive. It consists of orthoclase in short, well-formed prisms, a little plagioclase, abundant interstitial quartz, which is in optical continuity over large areas of the field, a little biotite in small ragged flakes, green hornblende, and abundant apatite.

"Basic patches" are rare in the Pulau Ubin granite. Those that do occur are large and angular, and slides were cut from a good example (*e*) (in quarry No. 1) with a view to comparing it with the rocks just described. It proved to consist of plagioclase with some orthoclase, abundant apatite, and equal quantities of biotite, pale-green monoclinic pyroxene, and green hornblende, part of which at any rate is derived from the pyroxene.

The following determinations of specific gravity have been made:—

Hornblende granite from the Municipality Quarry	2·68
Dark hornblende granite from Tanjong Jelutong	2·71
The rock *a* from the Municipality Quarry	2·89
The rock *b* from the Municipality Quarry	2·83
The rock *c* from the Municipality Quarry	3·01
The rock *d* from Changi	2·76
The basic patch *e* from quarry No. 1	2·88

It was thought at the time of collecting the specimens that *a* and *b* were but variations of the granite due to local differentiation, and there was no field evidence to show that they were of a different date of intrusion. But the fine-grained rock *c* is, in part at any rate, of later date than the granite, and the occurrence of the rhombic pyroxene in *a*, *b*, and *c*, and its (apparent) absence[1] from the granite and the basic patches, make it probable that this view was incorrect. Supposing, however, that it be granted that the rocks *a*, *b*, *c* all come from a separate magma, a further complication is introduced by the absence of rhombic pyroxene in the fine-grained rock *d* at Changi.

Granite containing rhombic pyroxene is not unknown in the Malay Archipelago. Mr. Wing Easton, describing the granite of West

[1] A quantity of granite, from the part of the quarry where the rock *c* is described as being mingled with it, was crushed, and the heavy minerals concentrated. Among them a few grains of the rhombic pyroxene were found, but this cannot be accepted as conclusive proof of the rhombic pyroxene being a constituent of the granite, as it may possibly have come from the other rock.

Borneo,[1] says that pyroxene seldom occurs, and is restricted to the varieties rich in hornblende. It occurs as monoclinic augite or rhombic hypersthene. The specific gravity of the Pulau Ubin rocks makes it hard to regard them as pyroxene-bearing granites: still, it may be noted here that in his *Beschrijving van een gedeelte van Sumatra's Westkust*[2] Dr. R. D. M. Verbeek describes "augite-bearing granite or quartz-augite-diorite",[3] and "augite-bearing syenite-granite"[4] whose chemical composition probably approximates that of the Pulau Ubin rocks. On the other hand, Charnockite[5] (sp.g. 2·67), the hypersthene-bearing granite of the Indian Peninsula, is distinctly separated from these rocks, not only in point of age but in mineral composition; while the references made by Rosenbusch,[6] Zirkel,[7] and Dr. Teall[8] to granite containing rhombic pyroxene do not favour their being regarded as phases of the normal granite.

The rocks *a* and *b* are not unlike some hypersthene-bearing rocks found by the writer in Sarawak. These are quartz-hornblende-norites, and the Pulau Ubin rocks *a* and *b* might be described as quartz-biotite-norite, but the amount of quartz present is considerable, and the extinction angles of the plagioclase are not high. The quartz-hornblende-norites of Sarawak are connected genetically with hypersthene andesites, lavas that are wide spread in the Malay Archipelago, and regarded as dating from the close of the Eocene. The granite of the Archipelago being earlier, it is possible that the Pulau Ubin rocks were derived from the same magma as the Sarawak norites, and should be regarded as belonging to a later period of eruption.

Considered apart, the fine-grained rock *c*[9] on Pulau Ubin, and the fine-grained rock *d* at Changi, are interesting on account of their resemblance to lamprophyres. The former might be described as enstatite-vogesite,[10] while the latter is an amphibole vogesite.

[1] N. Wing Easton, "Geologie eines teiles von West Borneo": Jaarb. v. h. Mijnwezen in Ned.-O.-Indie, Wetenschap. Gedeelte, Batavia, 1904.

[2] Batavia, 1883. [3] Op. cit., pp. 205–6. [4] Op. cit., p. 210.

[5] T. H. Holland, Mem. Geol. Surv. India, vol. xxviii, pt. ii, "The Charnockite Series, a group of Archæan hypersthenic rocks in Peninsular India."

[6] Rosenbusch, *Massige Gesteine*, p. 60.

[7] Zirkel, *Petrographie*, vol. ii, p. 13.

[8] J. J. H. Teall, "On some Quartz-Felsites and Augite Granites from the Cheviot District": Geol. Mag., 1885, p. 115.

[9] In "The Rocks of Pulo (=Pulau) Ubin" (Verhandel. Bataviaasch. Genootsch. Kunst. Wetenschap., vol. xxii, also published in *Essays relating to Indo-China*, ser. ii, vol. i, pp. 21–71) Logan notes a fine-grained rock, "blackish-green hornblende, or a very fine-grained black greenstone approaching basalt." This may be the writer's *c* weathered. Logan also mentions, however, a remnant of a basalt dyke between Pulo (=Pulau) Tam (Kitam?) and the west point of Pulo (=Pulau) Ubin, and he noted a bit of basalt adhering to a large syenitic block. This very likely refers to basic dykes cutting the granite such as are known elsewhere. Logan's observations were made prior to 1847, and those acquainted with the tropics will realize that all trace of the exposures mentioned may have disappeared.

[10] Rosenbusch (op. cit., p. 511) mentions hypersthene in a minette from near Freiburg and bronzite in Hartz Kersantites. The subordination of the biotite to the other ferromagnesian minerals in the Singapore rocks makes it necessary to regard them as vogesites.

VI.—The Mutual Interference of Artesian Wells.

By H. J. Llewellyn Beadnell, Assoc. Inst. M. M., F.G.S., F.R.G.S.

In the February and March issues of the Geological Magazine for 1908 I published a general account of the underground water-supply of the oasis of Kharga, in the Libyan Desert, and briefly referred to the influence of one bore on another.

Although the mutual interference of wells, a question of the highest importance in the development of artesian basins, has been touched on by several writers, I have not come across any published accounts of detailed experiments. It is indeed seldom that opportunities for such observations, on wells of which full boring records are available, present themselves. The results of certain experiments which I was recently able to carry out in the oasis of Kharga may therefore be of some value to geologists and engineers interested in water-supply.

The first observations I propose to record were made on two wells comparatively close together, Bore No. 5 being 570 metres W.S.W. of Bore No. 6, the outlet of the former being at 57·38 metres and of the latter at 59·18 metres above sea-level, a difference of 1·8 metres. No. 5 has an internal diameter of 5½ inches, is 645 feet deep, and 310 feet into the water-sandstones; No. 6 has a diameter of 8 inches, is 480 feet deep, and 200 feet into the sandstones. The two wells had been flowing continuously for a considerable period, and during the experiment neighbouring wells were kept shut down, so that there is no reason to suppose that the observations were affected by other bores. Bore No. 5, discharging 114 gallons per minute, was closed at 7 p.m. on June 12, 1907, and reopened after twelve hours, at 7 a.m. on June 13. The following hourly observations show the effects produced on Bore No. 6:—

Bore No. 5 closed at 7 p.m., 12/6/07.		Bore No. 5 opened at 7 a.m., 13/6/07.					
Time p.m.	Discharge of Bore 6, g.p.m.	Time a.m.	Discharge of Bore 6, g.p.m.	Time a.m.	Discharge of Bore 6, g.p.m.	Time p.m.	Discharge of Bore 6, g.p.m.
7.0	61·2	1.0	76·6	7.0	83·7	1.0	69·0
8.15	65·6	2.30	77·4	8.0	78·4	2.0	67·7
9.0	68·4	3.0	79·2	9.0	75·0	3.0	66·8
10.0	69·6	4.0	79·7	10.0	73·0	4.0	66·2
11.0	73·2	5.0	82·1	11.0	70·8	5.0	66·6
12.0	74·7	6.0	83·1	12.0	69·6	6.0	65·3
						7.0	63·0

This experiment shows that the closing of a flowing or the opening of a closed well, may produce a most marked effect on a neighbouring well within the short space of 60 minutes, even when the intervening distance is over 500 metres. In the above case the effect was most noticeable at first, there being a gain of 7 gallons per minute,

equivalent to about 12 per cent., in the first two hours. The total increase in the twelve hours amounted to 22½ g.p.m., or about 37 per cent. On reopening Bore No. 5 it is seen that the discharge of No. 6 at once commenced to fall, the loss being nearly 9 g.p.m. in the first two hours; afterwards the rate of decrease gradually diminished, until at 7 p.m., when the observations were discontinued, the flow had fallen to within 3 gallons of its normal.

A second series of observations was made between two bores considerably further apart, No. 4 being 835 metres N.N.W. of No. 42. The difference of level in this case was found to be 1·18 metres, the outlet of Bore 4 being at 60·74, that of Bore 42 at 59·56 metres above sea-level. No. 4 has an internal diameter of 4½ inches, is 463 feet deep, and draws from 63 feet of sandstone; No. 42 is 6 inches in diameter, 715 feet deep, and 225 feet into the water-sandstone. Previous to the experiment the former was flowing 36·75 and the latter 68·5 gallons per minute. Precautions were taken against other wells influencing the results, the nearest bores having been opened twenty-four hours previously and being kept in the same condition throughout the experiment. Bore 42 was closed down at 9 a.m. on March 4, 1908, periodical observations being then made of the discharge of Bore 4 during the next thirty-six hours. Briefly stated, the results were as follows:—the discharge of No. 4 had not perceptibly increased at the end of the first half-hour, but had done so after one hour. It continued to increase at a very slow rate, the net increase after thirty-six hours only amounting to 3 g.p.m., or between 8 and 9 per cent. In this case the sensitiveness is very much less than that between Bores 5 and 6, due doubtless to the wells being a greater distance apart and to the lesser difference between their outlet levels. In all probability there are a number of other conditions which combine with the above in determining the amount of interference, such as the positions of the wells with regard to the main lines of underground flow, the relative depths of the bores, and the thickness of the beds from which they draw their supplies.

The most marked example of interference which I have met with was in the case of two ancient wells at Dêr el Ghennîma, near the eastern escarpment of the depression. These bores are sunk on the crest of an anticlinal fold running north and south, and are only 88 metres apart. They have recently been cleaned out and their flows restored. The difference of level in the outlets is 2·07 metres, the higher well being 34½ metres, the lower 41 metres in depth. The opening or closing of the lower well produces an almost instantaneous effect on the higher, the difference in flow within thirty seconds amounting to over 10 per cent. A considerable number of observations were made, but those mentioned on the opposite page are sufficient to show the rates of decrease and increase.

The closing of the lower well is seen to have influenced the discharge of the upper bore to the extent of 100 per cent. in the space of thirty minutes, while the flow was trebled in twenty-four hours; on reopening the lower well the discharge of the upper fell to within 50 per cent. of its normal within forty-five minutes.

Upper Well flowed	18·2	g.p.m. when Lower Well was open (flow 50·3 g.p.m.),		
,, ,,	20·5	,, ,,	had been closed	10 minutes.
,, ,,	23·7	,, ,,	,,	20 ,,
,, ,,	26·3	,, ,,	,,	30 ,,
,, ,,	39·4	,, ,,	,,	24 hours.
,, ,,	35·6	,, ,,	had been open	30 seconds.
,, ,,	32·5	,, ,,	,,	2 minutes.
,, ,,	26·7	,, ,,	,,	7 ,,
,, ,,	24·9	,, ,,	,,	9 ,,
,, ,,	23·4	,, ,,	,,	10½ ,,
,, ,,	19·7	,, ,,	,,	15 ,,

The rate of flow of water through porous rocks has been investigated by a number of engineers and geologists, among whom we may mention Darcy, Hazen, King, Slichter, Knibbs, and Baldwin-Wiseman. The rate of flow through an underground sandstone depends upon a number of conditions, the most important being the size and shape of the pores between the component grains, the porosity or water-holding capacity of the sandstone, the temperature of the water, and the pressure acting on it. The yield of a well will depend not only on these factors, but also on the diameter of the bore, its depth into the water-stratum, the size and number of fissures passing through the bore, and last and most important of all, on the absolute height of the outlet. Although some of the above conditions may be known beforehand, the resistance to flow of the strata immediately surrounding a bore can never be more than approximately conjectured, as the size and mode of arrangement of the individual grains of any arenaceous sedimentary rock must always vary to a very considerable extent both horizontally and vertically within comparatively short distances, and on these factors depends to a great extent the capacity of the strata to transmit water.

Considerable difference of opinion exists among geologists as regards the relative importance of fissures in the production of artesian flows. That fissures exist, and exist abundantly, in the Nubian Sandstone is, I think, almost a matter of certainty; as I have shown in a former paper, fissures are visible to the eye in the upper sandstone (which does not appear to differ in any important respect from the artesian-water sandstone), and it is through them that the bulk of the sub-surface water is obtained. Moreover, the above experiments appear to almost demonstrate their existence, as it seems hardly conceivable that the closing of a bore could markedly affect the flow of another half a kilometre distant, if there were not a direct connection between the two by means of fissures.

It does not, however, necessarily follow that strongly flowing wells cannot be obtained from an unfissured sandstone, for although rapid flow through a compact sandstone is impossible owing to friction, which increases as the size of the channels decreases, the hydrostatic pressure can never entirely disappear, the rate of loss of hydrostatic head being dependent on the rate of flow. A rapid flow from a bore does not in any way depend on an equally rapid flow of water through the sandstone surrounding the bore; for instance, G. H. Knibbs, F.R.A.S., of the University of Sydney, has calculated[1] that although in a ten

[1] "The Hydraulic Aspect of the Artesian Problem": Proc. Roy. Soc. New South Wales, vol. xxxvii. p. 30.

inch bore, discharging 700 gallons a minute from a ten foot stratum, the water would have a velocity of 5½ feet a second at the bore itself, at a distance of one mile it would only be moving through the stratum at the rate of about $\frac{1}{20}$ inch per second, or 18 inches an hour.

Further consideration of the conditions governing artesian flows must, however, be reserved for a future occasion. In the meantime I have to tender my thanks to the members of my staff in the oasis for much valuable assistance in the keeping of records of all bores put down during the past three years.

VII.—Boulder Distribution from Lennoxtown, Scotland.

By A. MacEwen Peach.

ALTHOUGH the general path of the ice-sheet of the central valley of Scotland has been traced, no advantage has, up till now, been taken of the glacial distribution of boulders from a peculiar intrusive rock, which occurs in the Campsie Fells near Lennoxtown.

The rock of which the intrusion is composed was first described by Allport in the Quarterly Journal, Geological Society of London, 1874, vol. xxx, p. 559, as a porphyritic augite-olivine dolerite, and has later been determined by Mr. E. B. Bailey to be an essexite. He has also mapped the boundaries of the intrusion during the revision of that district by the Geological Survey.

From the distinctive characters of this rock, and the distribution of boulders from it in the neighbourhood of Milton and Kilsyth, Mr. Bailey was struck with its suitability as a means of determining the direction of ice-flow during the Glacial period, and it was at his suggestion that I undertook the task of extending his observations.

Mr. Bailey has shown that the Lennoxtown essexite is intruded into the lower portion of the interbedded volcanic rocks immediately overlying the Ballagan Beds of the Calciferous Sandstone Series, which forms the base of the Scottish Carboniferous formation. It borders the north side of the Crow Road leading from Lennoxtown to Fintry, about a mile north-west of the former, where the road crosses the great east and west fault which lets down the Hosies and Hurlet Limestones to the south against the volcanic series to the north. The outcrop of the intrusion is small, being only about 700 yards long and 100 yards wide; it has a roughly east and west trend, and lies between the 500 and 600 foot contour-lines.

In composition and structure the Lennoxtown essexite greatly resembles the well-known rocks of Brandberget in Kristiania and Crawford John in Lanarkshire. The variety which has been of most service in the present enquiry carries markedly porphyritic, idiomorphic, purple augites in a ground-mass much like that of a fine-grained gabbro, and thus presents a very distinct appearance, as, in the weathering of the rock, the augites remain prominent and more or less unaltered.

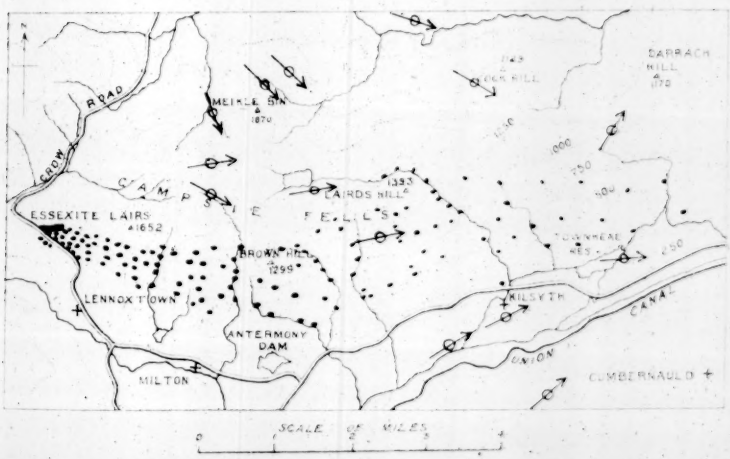
The only known rocks of similar external appearance, which are likely to be distributed as erratics in the district under consideration, are certain augite diorites of the West Highlands. Risk of confusion has been avoided by neglecting the very few boulders in regard to which there existed any room for uncertainty.

It has not been considered necessary to restrict the investigation to material occurring *in situ* in the drift: the dry stone dykes, which are mostly composed of surface boulders gathered from the immediate neighbourhood, have afforded the means of finding most of the larger specimens, and, since the essexite has never been quarried, they clearly afford a legitimate source of evidence. Many boulders, too, have been found washed out along the courses of burns and also along the shores of the Firth of Forth.

As may be seen from the accompanying map, the cone of distribution in the immediate neighbourhood of the intrusion is well marked, and the carry is wholly eastwards; uphill to the north and north-west of the intrusion there are no boulders, and, although about 100 yards along the road to the west of the intrusion a couple of boulders were found in a wall, they have evidently been carried there for building purposes. Downhill, to the south of the igneous mass, there are numerous boulders, forming a distinct cone, with the west end of the intrusion for its apex, and spreading out eastwards, till at the east end of the intrusion the cone is some 450 yards wide. About 100 yards downhill from the west end of the intrusion there are one or two small blocks now built into a wall: these may, however, have fallen downhill since Glacial times; they are angular, and show no evidence of having been affected by ice.

The southern edge of the cone crosses the Crow Road about a quarter of a mile from Lennoxtown, and runs eastward from the mass of essexite, the erratics being more numerous in the centre of the cone; still farther east the boulder track begins to ascend the hill till its northern limit, at a point due north of Lennoxtown, is about 800 feet above sea-level, and its breadth is between 600 and 700 yards.

Map 1.



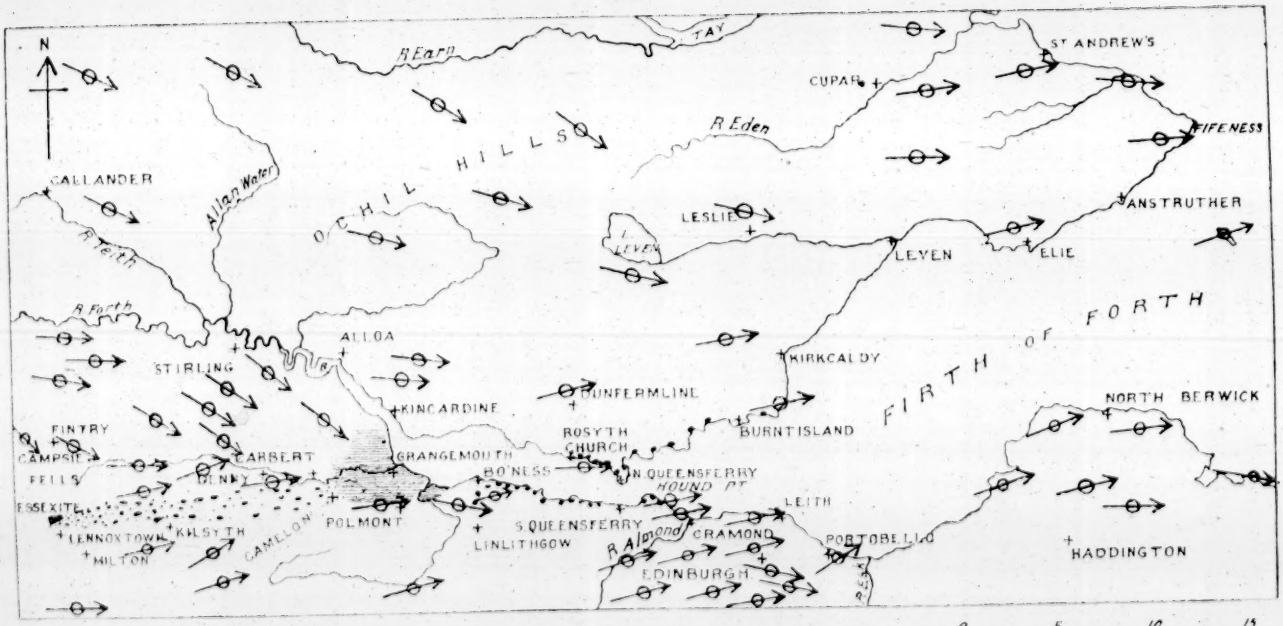
Map showing distribution of erratics in immediate neighbourhood of essexite intrusion.

Tracing the northern limit of the track as it passes eastward, we find that it ascends the higher ground which rises across its path. North of Milton the boulders of the northern limit have reached an elevation of 1,000 feet, while on Brown Hill they are more than 1,250 feet above sea-level. From Brown Hill the northern limit has a tendency to turn northwards, and from that point to Laird's Hill, due north of Kilsyth, the carry is E.N.E., the altitude at places being more than 1,300 feet. From this last point the carry is almost due east, the direction of ice-flow being unaffected by surface features. The northern limit is fairly well marked, and on the lower ground, north of Townhead Reservoir (see Map 1), its altitude is not more than 800 feet. To the east the boulders become scarcer, and the limit is not so well defined; it passes south of Denny and Larbert, and to the east of the latter place the trail is concealed, the drift being covered by the deposits of the various raised beaches of the Forth area.

The southern limit of the boulder track is also well marked. East from Lennoxtown the boulders do not come below the 300 foot contour-line till they reach a point east of Milton. Here also no influence on the direction of ice-flow can be attributed to the local surface features. For a short distance there is a slight southward deviation, but the eastern trend is resumed in the neighbourhood of Antermony Dam, between Milton and Kilsyth, and the direction even tends slightly to the north, running almost E.N.E. till at Camelon the boulder-clay is overlain by the Hundred Foot beach deposits already referred to. The boulder track up to this point, some 15 miles from its origin, is never more than 2½ miles across. It is well defined, and the number of erratics is very large in consideration of the size of the parent mass. Farther eastwards the raised beach deposits and the gravels of the Kaimes for a time obscure the boulder-clay, till, east of Polmont and north of Linlithgow, boulders are again found, the northern limit of the track entering the Forth just to the east of Bo'ness.

The coast all along the shores of the Forth is very suitable for the detection of the boulders, as it is covered just about high-water mark with stones derived from the destruction of a large amount of boulder-clay. Along the shore from Bo'ness to beyond South Queensferry these essexite boulders occur till the southern limit of the track is reached between Hound Point and Cramond. From Cramond to Portobello no essexite erratics were found, although this shore is a very favourable one for their observation, the boulders on the shore representing the result of the destruction of a very large amount of boulder-clay. It has not been considered necessary to look for boulders on the shores immediately east of Portobello, but careful research on the promontory of North Berwick has failed to reveal any erratics from the Lennoxtown essexite, a result which might have been predicted from the trend of the glacial striæ. Thus the southern limit of the track evidently lies within the area now covered by the Firth of Forth. This conclusion has been drawn from a consideration of observations on the ice-mouldings and striæ between Edinburgh and North Berwick, which show that the direction

MAP 2.


N
R Earn
TAY
ST ANDREW'S
CUPAR
R Eden
FIFENESS
CALLANDER
Allan Water
R Teith
OCHIL HILLS
LESLIE
LEVEN
LEVEN
ANSTRUTHER
ELIE
R Forth
ALLOA
STIRLING
KIRKCALDY
FIRTH OF FORTH
KINCARDINE
DUNFERMLINE
NORTH BERWICK
FINTRY
CAMPSIE FELLS
CARBERT
GRANGEMOUTH
ROSYTH
CHURCH
BURNTISLAND
BO'NESS
N. QUEENSFERRY
HOUND PT
ESSEXITE
DENNY
LEITH
LENNOXTOWN
KILSYTH
CAMELON
POLMONT
S. QUEENSFERRY
LINLITHGOW
R Almond
CRAMOND
PORTOBELLO
HADDINGTON
MILTON
EDINBURGH
P.S.
0 5 10 15 Miles
ESSEXITE BOULDERS
RAISED BEACH DEPOSITS
GLACIAL STRIÆ TAKEN BY PERMISSION FROM GEOLOGICAL SURVEY MAPS

of ice-flow was well to the north of east (Map 2). On the northern shore of the Forth the farthest west point at which the boulders have been found is Rosyth Church, which marks therefore the northern limit of the track, the tendency of the ice-carry from Linlithgow and Bo'ness, therefore, being approximately E.N.E. From Rosyth to a point considerably east of North Queensferry a number of essexite boulders are to be seen on the shore, and the northern limit is again reached between Burntisland and Kinghorn, and from this point eastwards along the shores of Fife to Fife Ness these essexite boulders have not been observed. The northern limit of the track, therefore, also lies within the boundaries of the Firth of Forth until as far east as Fife Ness. At Hound Point, 35 miles from the source, the last place at which an estimate can be taken, the track is only some 4 miles across. From this point eastwards the southern limit of the track lies within the Forth Estuary.

The trend of these essexite erratics agrees closely with the other indications of the ice-movement, such as the direction of the striæ, ice-mouldings, and drumlins. It may be noted that the striæ (see Map 1) on the high ground of the Campsie Plateau, north of the boulder track, run in a direction approximately E. 30° S., making an angle of about 60° with the direction of the boulder track. This apparent discrepancy is most probably due to the well-known phenomenon of differential movement in the different layers of the ice-sheet. The vertical distribution of the boulders is important, showing that nowhere has the existence of higher ground interfered with the course of the ice. During the eastward movement the erratics were carried directly up from the 500 or 600 foot level to over 1,300 feet in a distance of about 3 miles.

The distribution, both vertical and horizontal, of these essexite boulders points, then, definitely to the action of land-ice at a period when the minor surface features of hill and dale in the central valley of Scotland had little or no effect in determining the direction of the ice-flow—obviously, therefore, about the period of maximum glaciation.

The distribution of the essexite exclusively to the eastward of the intrusion seems to show that there cannot, at any stage of the glaciation, have been a reversal of the flow in the central valley of Scotland. Indeed, the narrowness of the trail formed by these boulders allows of but little variation in the direction of motion. Such variation might be expected if, as Professor Kendall suggests,[1] the Scandinavian ice ever exerted such a powerful damming effect at the mouth of the Forth as to intensify the congestion in the Clyde and Irish Sea Basins.

There is no evidence of any redistribution of these boulders by later local glaciation, although local corrie glaciers are known to have existed in many parts of the Campsie Fells.[2] Moreover, the fluvio-glacial conditions which prevailed during the retreat of the ice-sheet have evidently had but little effect in widening the track. On the shores of the Forth, again, the action of the sea at its successive

[1] P. F. Kendall, Q.J.G.S., 1902, vol. lviii, p. 565.

[2] See E. B. Bailey, Sum. Prog. Geol. Surv. for 1907, pp. 97–8.

levels must have tended to concentrate the coarser drift material, but we cannot suppose that the accompanying slight transportation has had any effect in modifying the general distribution of the boulders.

On considering the number of boulders observed, and the fact that these must of necessity be merely a small proportion of the total number derived from the intrusion, the result is somewhat surprising. If this may be taken as an indication of the transport of material throughout the whole Strathblane Valley, the amount of modification which that valley has undergone at the hands of the ice must have been very considerable. It is highly probable, however, that much of the material may have been in the condition of a talus before the advent of the ice, but that obviously does not affect the question of the extent of erosion by the ice.

Through the kindness of Dr. Horne I have been allowed to place on my maps a number of observations on Glacial Striæ from the 6 inch working copies of the Geological Survey Maps.

REVIEWS.

I.—The Geology and Scenery of the Grampians and the Valley of Strathmore. By Peter Macnair, F.R.S.E., F.G.S., Curator of the Natural History Collections in the Glasgow Museums, etc. 2 vols. 8vo. pp. xiv + 195 and xii + 199, with 163 plates and 10 folded and coloured maps and diagrams. James MacLehose & Sons, Glasgow.

IN two handy volumes abounding in a wealth of illustration the author presents an account of the geology of a wide but ill-defined tract which centres round Perthshire. That great structural break, the Highland boundary fault, cuts the region into two parts. The one lies within the Highlands upon the metamorphic rocks, whilst the other stretches over the foot-hills of Old Red Sandstone, the plain of Strathmore, and includes the volcanic ridges of the Ochil and Sidlaw Hills. The title of the book, therefore, is misleading, for only a portion of the mountainous region sometimes called the Grampians receives any attention, and by the inclusion of 'Scenery' in the title a fuller and more scientific treatment of its evolution might be anticipated. The area actually described presents such varied characters that naturally it includes many points of general interest to geologists. Some of the unsolved problems, such as the metamorphism, age, and structure of the Highland schists, are the largest with which the Scottish geologist has to deal. For his description the author has culled information from many available sources, whilst he has himself an intimate knowledge of certain tracts, which are treated in great detail. On most subjects the views here put forward do not differ essentially from those generally accepted. A special claim is made that the book contains a considerable amount of original research, but it would be difficult to show that its publication has advanced any of these problems a single step towards solution. Whole chapters of the book are simply reproductions

of papers published elsewhere. The chapter on the physical conditions under which the Old Red Sandstone was laid down is taken practically verbatim from papers published twelve years ago by Mr. James Reid and the author in the GEOLOGICAL MAGAZINE. We must take exception to the reprinting, without emendation or comment, of personal statements, which on their first publication called forth a remonstrance, and then an explanation by the authors. Throughout the book generally we can only regard his handling of the opinions of well-known geologists as particularly unfortunate.

As a description of the geology of a highly interesting district the book meets a want. The author's enthusiasm is evident in his writing, and throughout the greater portion of the book he easily holds the reader's attention. Whilst the style helps to arouse interest in the theme, his descriptions suffer from a lack of clearness. They are too detailed and too technical for the general reader, and too inexact for the geological student. To give an instance, mica-schist is described thus:—"Mineralogically, mica-schist consists of an aggregation of quartz and mica arranged in alternating wavy lamina-planes of schistosity. Structurally, the quartz presents a granular character, having been derived from the breaking up of the original quartz grains in the clastic rock. The mica, which may either be muscovite or biotite, is entirely authigenic, and takes the form of plates, which are generally basal sections of the mineral" (p. 115). Technical terms are occasionally introduced unnecessarily, and are often left unexplained, although the opening chapter would lead us to infer that the book is intended to appeal to the novice and the general reader. There is also an occasional lack of consistency in the statements of results. For example, the main mass of the mountain chain, whose basal wreck is now represented by the Highlands, is shifted about to suit requirements. In many references (e.g. p. 161) he places "the backbone or core of the great geanticlinal" along the Ben Lawers ridge" in the Central Highlands. After studying his 'marginal fan', he concludes (p. 182) that "by carefully considering the fragments that are now left of this ancient chain, it appears that the great central massive must have risen over what is now the Midland Valley of Scotland". But when discussing the conditions under which the Lower Old Red Sandstone was deposited, this position is inconvenient, and we read (p. 23, vol. ii) that "the great mass of the mountain chain must have lain to the north-west of the present Old Red Sandstone area".

The work is illustrated by over 150 photographic reproductions of scenery, fossils, rock-specimens, and microscope sections, for which the author is indebted to numerous friends. The views illustrating hill-top scenery are amongst the finest we have seen. Many of them are really beautiful pictures, and they have been carefully reproduced. The photomicrographs are not all equally good, those illustrating the schistose rocks in particular being fuzzy. They should have had fuller descriptions attached, as it is impossible to recognize the minerals at sight. There are in addition seven geological sketch-maps printed in colours and other maps and sections.

The first volume is devoted to the Highland rocks. The opening

chapter expounds some of the principles of geology, and is apparently intended for the novice. The following Historical Introduction plunges into technicalities at once, and is stiff reading for the novice who has only the first chapter to guide him. It consists mainly of an exposition of Nicol's work on the structure of the Southern Grampians and a summary of the author's views as developed in the succeeding chapters.

In chapter iii, which gives an outline of the physiography and geology, the former subject is largely taken up by lists of mountain summits, tributary streams, and the names of hills seen from certain view points, from which the reader is likely to emerge with the haziest of notions about the physiography of the region. The outline of the geology is a more useful summary, though such phrases as the "summit of the synclinal trough" are puzzling, and we note the remarkable statement that "the presence of *roches moutonnées* indicates the existence and work of the later glaciers".

Chapters iv and v contain a description of the rocks of the Highland area. They are classified into schists of sedimentary origin, schists of igneous origin, and intrusive rocks later than the foliation of the schists. The author points out that the bulk of the rocks were laid down as sediments of the ordinary type, and that many of them retain traces of their original fragmental character. The weak and fine-grained sediments are more affected by metamorphism than the harder rocks, but, apart from the original nature of the sediments, the metamorphism which is feeble in certain areas increases in intensity in others, often at no great distance. The author considers the metamorphism to be mainly dynamic, the rocks having been subjected to great pressure, accompanied by a high temperature, during the operation of the mountain-building processes which upheaved the Grampians. He does not distinguish any effects particularly due to thermal metamorphism, and whilst admitting "high degrees of heat" he offers no opinion as to its source. In areas of feeble metamorphism, such as the belt of slates on the margin of the Highlands, one set of cleavage planes only is recognized, but in the zone of the Ben Lawers schist the first cleavage planes are folded and crossed by a second set of cleavage planes developed during the folding of the first set. In some districts tertiary and even quaternary cleavages may be traced, and these, the author thinks, were produced by a series of intermittent movements. The author does not appear to distinguish cleavage from foliation, and slaty cleavage is not separated from the false cleavages. One of the latter structures, strain-slip-cleavage, is referred to as 'strain-slip', but if the full title be considered too unwieldy, 'slip-cleavage' would be a more suitable abbreviation. The mineral changes which accompany the development of foliation are scarcely mentioned.

It is well known that the schists which enter into the formation of the Grampians traverse that region in a north-west and south-east direction. These the author divides into the following zones, omitting a narrow band of black slates, cherts, and limestones, the supposed Arenig rocks of the Survey on the Highland frontier, and the Leny grits for consideration in a later chapter: (1) The Lower Argillaceous

zone: (2) the Lower Arenaceous zone, with the 'green beds' at the top: (3) the Loch Tay Limestone: (4) the Garnetiferous Schist zone: (5) the Upper Argillaceous zone; and (6) the Upper Arenaceous zone. This terminology is somewhat cumbrous, and the use of 'Upper' and 'Lower' will appear premature to most geologists in view of the difficulties of reading the Highland sequence. The author writes with remarkable assurance on this point. His main argument appears to be that of Sir Archibald Geikie and the Geological Survey, viz. that the simplest interpretation of the structure places each inner belt above the succeeding outer one. This order is taken to be the order of original deposition, but it is quite possibly illusory. In fact, if the structural theory adopted in a later chapter were applicable to the Highlands as rigorously as the author would have us believe, we should expect the oldest beds just where he puts some of his youngest, i.e. along the axis of the denuded antielinorium.

The author then proceeds to a more detailed description of the 'zones', which would have been much easier to follow had the names of the localities mentioned in the text been inserted in the large geological map (on a scale of 6½ inches to 1 mile) provided at the end of the volume. Many more place-names could have been inserted without obscuring the map. Commencing on the Highland border, we meet first the Lower Argillaceous zone, comprising the clay-slates of Aberfoyle, which on the Clyde pass into the condition of phyllites. Immediately to the north-west comes the Lower Arenaceous zone, containing the massive grits of Ben Ledi and other grits, greywackes, and more argillaceous schists, up to and including the 'green beds'. The intense metamorphism shown by these rocks around the head of Loch Lomond as compared with their development elsewhere does not receive adequate treatment, Cunningham-Craig's paper on the subject not being referred to. The peculiar 'green beds' receive a short description. Evidence proving their clastic origin is brought forward, but their distinction from the intrusive sills of epidiorite with which they have been confounded is left to be inferred. In the Loch Tay Limestone zone schists on both sides of the limestone are sometimes included. The course of the limestone outcrops in the neighbourhood of Loch Tay is traced in unnecessary detail, and the evidence afforded by the limestone of intense buckling and compression is pointed out.

To the north-west of the Loch Tay Limestone zone lies the Garnetiferous Schist zone. This comprises a belt of mica-schists usually of considerable breadth, and traceable like the other zones from sea to sea. Garnets occur throughout this horizon, not only in the mica-schists, but also in the epidiorites and hornblende-schists. The author considers that the garnets are a product of dynamic metamorphism, apparently in the sense that they represent a phase of the regional metamorphism, which increases in a general way from the frontier towards the Central Highlands. Beyond the Garnetiferous Schist zone lies the Upper Argillaceous zone, comprising the belt of rocks known as Ardrishaig phyllites, calc-sericite schist, or Ben Lawers schist, in the different districts which it traverses. A band of black graphitic schist, cropping out along the north-west

side of the calc-sericite schist of Central Perthshire, is also included in this zone. The metamorphism of these rocks increases along the course of their outcrop from Ardrishaig to the head of Loch Fyne, as shown by J. B. Hill. In the Upper Arenaceous zone the author would now include only the Central Highland quartzite, transferring the Blair Atholl limestone to the top of his Upper Argillaceous zone. He adopts Cunningham-Craig's conclusions for the Blair Atholl district that there is an upward succession from the Ben Lawers schist, through black graphitic schist and Blair Atholl limestone into quartzite. He also accepts the view that there was a period of local erosion at the base of the quartzite, when the boulder-bed of Schichallion and Islay was laid down. The Moine gneisses are classed with the quartzite in the Upper Arenaceous zone in the text, but in the tabular statement (p. 96) they are kept outside it and marked as of uncertain position. The author's acquaintance with these rocks must be slight. He adduces "their peculiar granulitic structure" as evidence of their sedimentary origin.

The age of the Highland schists cannot at present be determined. Pebbles of these rocks occur abundantly in the conglomerates of Lower Old Red Sandstone age, and they are also found in certain conglomerates of the Upper Silurian of the south of Scotland, but how much older they may be it is impossible to say. However, developing in a later chapter a theory to account for the structure of the Grampians, the author takes it that the sediments which ultimately formed the Highland schists were laid down in a sinking geosynclinal in the old continent of Archæan gneiss. And in the final chapter of the work we read that the first denudation of the upheaved Highland chain began with the deposition of the Torridon Sandstone, and was continued through Cambrian times. It is evident, therefore, that the author opines that the Highland schists belong to some formation intermediate in age between the Archæan gneiss and the Torridon Sandstones, but this is little more than a guess.

(*To be continued.*)

II.—A Treatise on Gold and Silver. By Walter Crane, Ph.D. pp. 727 + x, with 20 illustrations and 9 plates. New York, John Wiley & Sons; London, Chapman & Hall, 1908. Price 21s. net.

WE learn from the preface that the Carnegie Institution of Washington has in hand an Economic History of the United States. Dr. Crane's elaborate treatise is the first instalment of that work, and is eloquent testimony to the comprehensiveness of the scale upon which it has been planned. The author has evidently spared no pains to make this history of the mining of gold and silver in the United States as complete and exhaustive as possible. Extensive quotations are introduced from original papers, particularly in the chapters dealing with the occurrence and association of gold and silver and their geological distribution, and references are in all cases given to enable the reader, who so desires, to look up the original sources. By giving the actual words of a writer the

possibility of misinterpreting his remarks is removed: but this plan has the almost unavoidable disadvantage of entailing some repetition in statement and a want of smoothness in style, and leaves the reader in doubt as to what the author's views may be on debatable points.

After touching in the introductory pages on the influence of the mining of the precious metals upon the industrial life of the United States, and especially the development of railroads, Dr. Crane devotes a chapter to the history of the discoveries of gold and silver in North America, the earliest date given being as far back as 1513, when a cacique of gold was reported to Ponce de Leon while lying off the coast of Florida. The next chapter is concerned with the occurrence and association of gold and silver, and includes a discussion of the theory of ore formation and the occurrence of gold in gravel; it is followed by a short chapter on the companion question, viz. their geological distribution, showing that gold is to be found in rocks of all ages, contrary to the views of early geologists. The mining engineer will doubtless consider the succeeding chapters on the mining of the ores and gravels, the extraction of values, and the production of gold and silver the most important part of the book. A full and admirable account is given of the various methods of mining — gravel-mining, hydraulic-mining, river-mining, drift-mining, dredging: the modes of extracting the metal in wide veins, in narrow veins, in bedded deposits, and in masses, typical mines being described in full detail; various important practical points such as timbering, drainage, and ventilation; and the principal processes, both mechanical and chemical, of obtaining the metal from the ores, such as amalgamation, concentration, chlorination, and cyanidation. As an appendix we find a series of valuable tables—discovery of gold and silver mines and districts, occurrence and mineralogical association of gold and silver, geological distribution of gold and silver, yield of ores by districts and mines, yield of gravels by districts and mines, fineness and value of gold and silver. A copious index brings the book to a close.

The illustrations have mostly been used before in other publications; they are, especially in the case of the half-tone blocks, often far from distinct and not up to the standard that might have been expected.

III.—Triassic Ichthyosauria, with special reference to the American Forms. By John C. Merriam. Mem. Univ. California, 1908, vol. i, No. 1. pp. 196, with 18 plates and 154 text-figures.

SINCE 1895 Dr. John C. Merriam, of the University of California, has published several small papers on Ichthyosaurian remains from the Trias of California. Between 1901 and 1907 ten expeditions were sent out by the University of California to collect ample material, and the result was the acquisition of considerable parts of no less than fifty skeletons. Dr. Merriam visited and studied the European collections to prepare for the investigation of these new specimens, and he has now published an exhaustive memoir on Triassic Ichthyosauria

in general, summarizing and extending his earlier work, and ending with a discussion of the classification of the Ichthyosaurian Order.

An exact description of the Ichthyosaurians of the Triassic period has long been wanted, because it seemed likely that they would prove to be links between the typical members of the order and some early group of marsh-dwellers or land-dwellers. Dr. Merriam, in the memoir before us, begins to produce the desired material, and shows how in many respects the few known genera are really links in the ancestral series. The Triassic Ichthyosauria have relatively larger limbs than their successors, and were probably less dependent on a tail-fin for locomotion. The number of phalanges in the digits is less than in *Ichthyosaurus* proper; the interclavicle is often triangular in shape (not T-shaped), thus approaching that of Labyrinthodonts and some primitive Rhynchocephalians; and the pelvis is large, with much-expanded pubes and ischia, as in many other early reptiles. The skull is short compared with the length of the trunk, and the eye is not so large as in later forms. The teeth are often fixed in sockets, and not quite similar in shape in different parts of the jaw. The atlas and axis are not fused together, and the end of the vertebral column is not so sharply bent downwards in the tail-fin as in *Ichthyosaurus*. The Triassic Ichthyosauria are therefore less completely adapted for an aquatic life than their successors in later Mesozoic periods.

Dr. Merriam classifies the Ichthyosauria in two families, Mixosauridæ and Ichthyosauridæ. The Mixosauridæ are exclusively Triassic, so far as known, and have been found in Europe, Spitzbergen, North America, and perhaps New Zealand. *Mixosaurus* is described from Europe, while *Cymbospondylus*, *Toretocnemus*, *Merriamia*, *Delphinosaurus*, and *Shastasaurus* occur in California and Nevada. The detailed descriptions are illustrated by numerous text-figures and eighteen plates.

IV.—Calcareous Concretions in Coal Seams. By M. C. Stopes and D. M. S. Watson. Phil. Trans., 1908.

AN important and interesting paper "On the Present Distribution and Origin of the Calcareous Concretions in Coal Seams, known as 'Coal Balls'", has been contributed by M. C. Stopes and D. M. S. Watson (Phil. Trans., 1908, vol. cc, series B, pp. 167–218). While recognizing that the origin of the 'coal balls' or 'bullions' is distinct from that of the coal seams in which they occur, yet their investigation tends to throw light on the origin of the latter.

Analyses show that the coal balls are principally made up of calcium and magnesium carbonates, in many cases in the proportion in which these carbonates occur in dolomite, and altogether forming 90 per cent. or more of the mass. The amount of alumina and silicates was found to be so minute (averaging less than 0·3 per cent.) as to be negligible, showing that muddy or detrital matter was absent and that practically pure plant masses were mineralized by the mixture of carbonates.

Other concretions known as 'roof' or 'Goniatite nodules' frequently contain isolated plants, but are always found in the roof

or shale above and not in the coal itself; and these, although otherwise very similar to the coal balls, were formed under conditions less free from detrital matter, as they contain from 1 to 6 per cent. of silicate of alumina.

The main conclusions are that (1) the coal balls were formed in the position in which they are now found, and probably also the coal itself was likewise formed *in situ*; (2) the sea water was fundamentally important during the coal ball formation in acting both as a temporary preservative and as the source of the calcium and magnesium carbonates required for petrifaction; and (3) the plants in the roof nodules represent a different flora from that found in the coal.

The conditions under which these phenomena were produced are to be found in the mangrove-swamps to-day, where "Groves of large trees with smaller herbs and ferns finding place between and around their stems grew in the flat swampy levels between the higher ground and the sea".

The authors give an interesting word-picture of the features attending the formation of the coal balls, which are "relics of a forest which grew quietly in a swamp in the place where they are now found, while the plants in the shales and in the roof nodules above had drifted out to sea from other districts and bear in the character of their structures the impress of the different type of land on which they lived".

V.—The Geology of the Country around Andover. By A. J. Jukes-Browne, B.A., F.G.S.; partly from notes by F. J. Bennett, F.G.S., and H. J. Osborne White, F.G.S. pp. v, 67, with 12 text-illustrations. Price 1*s.* 6*d.* Colour-printed map, Sheet 283, 1*s.* 6*d.*

The Geology of the Country around Henley-on-Thames and Wallingford. By A. J. Jukes-Browne and H. J. Osborne White. pp. vii, 113, with 13 text-illustrations. Price 2*s.* Colour-printed map, Sheet 254, price 1*s.* 6*d.*

IN the memoir on Andover we have a description of a large Chalk area which extends from the eastern borders of Salisbury Plain near North Tidworth, through Andover and Whitchurch to Overton. On the northern margin are included the eastern end of the Vale of Pewsey, and the famous 'Valley of Elevation' of Burghclere and Kingsclere, an inlier of Upper Greensand with steeply inclined Chalk on the north bounding a tract of the Eocene strata of the London Basin.

The greater portion of the work is occupied with an account of the stratigraphy and palæontological zones in the Cretaceous rocks, and here Mr. Jukes-Browne acknowledges aid given by Mr. C. Griffiths, of Winchester, and Mr. R. M. Brydone, who have zealously worked at the fossils in the Chalk. The Eocene strata include Reading Beds and higher divisions up to the Bracklesham Beds seen at Highclere. Clay with flints and other superficial deposits are likewise described, but we find no reference to the Palæolithic implements of St. Mary Bourne,

a locality made famous by Mr. Joseph Stevens in "A Descriptive List of Flint Implements found at St. Mary Bourne", 1867.

The memoir on Henley on-Thames includes brief descriptions of the Kimeridge Clay, Portland Beds, and Lower Greensand which occur in the north-western portion of the area; but the bulk of the work is taken up with detailed accounts of the Upper Cretaceous rocks and fossils by Mr. Jukes-Browne, and of the Eocene and superficial deposits by Mr. Osborne White. The Chalk forms the dominant features over more than half of the area, and the junction of the middle and upper divisions occurs along the crest of the Chiltern Hills, overlooking the Thames Valley at Wallingford on the west and sloping towards Henley-on-Thames on the south-east, with a marked inlier of Middle Chalk bounded by the locally prominent Chalk Rock between Stokenchurch and Henley. This last-named feature is shown on a special map in the memoir, as the Chalk Rock was found by Mr. Osborne White to occur over a larger area than was depicted on the colour-printed map. Eocene formations (Reading Beds and London Clay) occur only as outliers, as in the picturesque regions of Nettlebed and Lane End.

Those concerned in studying the origin and history of the Thames Valley will find much to interest them in Mr. White's chapters on the Scenery and Superficial Deposits. His record of the occurrence of quartzose gravels in the Reading Beds of Lane End is noteworthy in connection with the origin of the 'Pebble Gravel'. In his opinion this much debated deposit may be ascribed mainly to the wasting of Lower Eocene pebble-beds, a process that may have commenced in Oligocene times and have continued ever since. The Clay-with-flints likewise has a long history, when regarded as "a product of the decomposition of the Chalk and the disintegration of the Eocene and later sediments formerly covering that rock".

With regard to the Plateau Gravels, they are divided by Mr. White into the 'Quartzite Gravel', characterized by liver-coloured and grey quartzites from the Bunter, and the possibly newer 'Angular Flint Gravel'. He observes, "That the quartzitic Plateau Gravel bordering the Thames Valley is largely of fluviatile origin can, however, hardly be doubted; and, although proof is lacking, the present writer is much disposed to think that the exotic material which occurs so abundantly in that drift, and which, in the Henley district, appears at first in rounded stones of small size in the upland Pebble Gravel, 400 to 500 feet above the Thames, was being carried into the region of the Upper Thames basin long before the commencement of the Pleistocene 'Ice Age'."

Mr. White further remarks that "The gravel is decalcified and, save for a few palæoliths, has yielded no fossils. As to its age, little is certainly known. The lower terrace deposits—i.e. those up to 200 feet above the level of the Thames in their neighbourhood—are probably all of Pleistocene date; the highest may be of Newer Pliocene age". These conclusions are of great interest, and will be helpful in all studies of the Thames Valley. Some of the Palæolithic implements above referred to have been found in Friar Park, Henley.

The newer 'Valley Gravel' is duly described, and, among other points of interest, attention is directed to the cones or fans of chalk-rubble and rubbly gravel which occur at the mouths of the combes in the neighbourhood of Henley.

The Geological Survey is to be congratulated on having obtained the services of Mr. Osborne White in the description of the later deposits in the area to which this memoir refers.

VI.—The Geological Structure of Western Cornwall. By Uppfield Green, F.G.S. 8vo. Penzance, November, 1908. In advance from the 95th Report of the Royal Geological Society of Cornwall. Price 1*s*.

THE author's views as to the age of the rocks in Western Cornwall have been public property since his paper appeared in the Geological Magazine for August, 1904. In this pamphlet he gives the sequence of the beds, as he believes it, in detail, and contrasts it with that of the Geological Survey, who regard the beds between the known Devonian on the north and the south coast as Ordovician or Cambrian, although some of these beds have been shown to contain lenticles of Upper Silurian limestones. Mr. Green regards them all as Gedinnian, and gives a sketch-map and section in support of his views. He appears to suggest (on p. 2) that the published one-inch maps issued by the Survey do not agree with, and are not so accurate as, the six-inch maps on which the mapping was done. He promises further papers on the subject.

VII.—Brief Notices.

1. British Jurassic Echinoids.—The last number of the Proceedings of the Cotteswold Naturalists' Field Club (vol. xvi, pt. ii) contains "Notes on some Echinoids from the Lias of Worcestershire, Gloucestershire, and Somerset", by E. Talbot Paris, who has also contributed the systematic notes and descriptions to the following paper, "On the Stratigraphical and Geographical Distribution of the Inferior Oolite Echinoids of the West of England," by L. Richardson and E. Talbot Paris. The latter paper should be of particular service to those working on that wonderfully rich and condensed series of rocks known as the Inferior Oolite; it contains interesting remarks on distribution, migration, and parallel development. Mr. Paris must be welcomed as a new student in this field, and one who seems inclined to work on correct lines. In the arrangement of his matter the influence of Mr. Richardson is obvious, and we wonder sometimes that it was not carried a little further. In turning out new species Mr. Paris is a little rash; many are based on unique specimens, and when this is not the case a holotype (as Mr. Richardson would probably call it) is not selected. The new species *Diademopsis hettangiensis* is not figured, nor is it compared with the many other Hettangian species previously referred to that genus. Mr. Paris refers *Hemipedina Etheridgei* to *Diademopsis*, forgetting that it is the type species of *Hemipedina*. He states that in *H. perforata* there are only granules between the main interambulacral tubercles, but does not give his

evidence. His enclosure of authors' names within round brackets is not consistently carried out; but that is a trivial matter, and one gladly recognises that the meaning of brackets is understood. What, if we may judge from the list of helpers, is not understood is that before proposing new species and varieties the type-specimens of recognised species should be referred to, and that the rich collections of the British Museum are open to all serious students. The omission (so it seems) to consult them is not a trivial matter.

2. South Africa.—Further South African material reaches us in the shape of papers by W. D. Lang on Polyzoa and Anthozoa from the Upper Cretaceous Limestone of Need's Camp, Buffalo River, and H. Woods' paper on Echinoidea, Brachiopoda, and Lamellibranchia from the same district. Lang's researches lead him to conclude that the age of this deposit is Senonian or Danian, and Woods' refers it to "a late stage in the Chalk". F. R. C. Reed has examined a large series of additional fossils from the Bokkeveld Beds, and finds that his conclusions as to the characters and relations of these beds do not require any modification in consequence of the new material received. He gives a complete list of this interesting Devonian series and notices all the new species. Dr. Broom describes the greater part of a skeleton of *Propappus omocratus*, a Pareiasaurian found in 1907 near Graaff Reinet; *Alopecodon*, *Hyænasuchus*, *Trochosuchus*, and *Pardosuchus*, four new genera of Therocephalian reptiles, and a new Labyrinthodont *Rhinesuchus Whaitsi* of Permian age. All these papers appear in the Annals of the South African Museum, 1908.

Dr. A. W. Rogers has published in the Twelfth Annual Report of the Geological Commission of the Cape of Good Hope (1908) the result of his survey of parts of Vryburg, Kuruman, Hay, and Gordonia, a large area simple in the west and north-west, but complicated in the central part where the rocks are almost completely hidden under sand. Karroo beds occur in an extensive but thin layer, but beyond the recent fresh-water mollusca in a few pans no fossils appear to have been found. A. L. Du Toit has papers in the same publication on portions of Mafeking and Vryburg and portions of Hopetown, Britstown, Prieska, and Hay, and here again fossils are almost absent; a few plant remains alone rewarding the surveyor. Progress is steady and continuous, and in a few years time the devoted band of geologists now working in South Africa will be enabled to provide a geological map which will considerably advance our knowledge of that interesting area.

3. Canada.—A batch of papers from the Canadian Department of Mines dated 1907 and 1908 shows the usual activity in geological matters. The Similkameen district of British Columbia is described by C. Camsell, who finds there Post-Oligocene, Oligocene, Cretaceous, Post-Palæozoic, and Palæozoic deposits, fossils occurring only in the Oligocene lignites and the Cretaceous sandstones. D. D. Cairns writes on a portion of the Conrad and White Horse mining districts of the Yukon, and his paper, chiefly devoted to mining, contains interesting particulars of the Carboniferous or Devonian, Triassic (?), Jurassic, and Cretaceous sediments, all of which are shown on a map accompanying the report. Dr. R. W. Ells writes on the Landslide at

Notre Dame de la Salette, Lièvre River, Quebec, and John A. Dresser on a recent discovery of gold near Lake Megantic, Quebec. Another report, by O. E. Leroy, which includes the coast from north of Texada Island to the United States boundary, is highly important, but the Government printer has been rather unkind to the author in that he has made up his report in pages as follows: 22, 23, blank, covering letter, 18, 19, 8, 9, 39, 31, 12, 13, etc., and thus makes it a little difficult to follow. We gather, however, that Devono-Carboniferous, Triassic, Jurassic, Cretaceous, and Eocene beds have been identified, and that the beds are a good deal disturbed by volcanic rocks.

4. Fossil Pearls.—Although John Woodward, in 1723, referred to the fact that fossil shells, as well as recent, had "pearls and the like still actually growing upon them", and Goldfuss had figured, in 1836, an example of *Inoceramus* showing the existence of pearls, it was not till 1851 that these bodies were definitely figured and described. In that year John Morris wrote a paper in the Annals and Magazine of Natural History upon material in the Wetherell Collection, and this material is still preserved in the British Museum. Mr. R. Bullen Newton has now collected together the previous information, added a sketch of the occurrence and formation of pearls in general, a note on fossil pearls, and then described and illustrated many examples which have come under his own observation. In this paper (Proc. Malac. Soc., 1908, vol. viii, pp. 128–39) Mr. Newton distinguishes between true pearls and 'blisters', which latter are caused by the intrusion of foreign bodies between the mantle and the shell, etc. True pearls are known by their radiating and concentric structures as shown in section. Fossil pearls are described from *Volsella*, *Inoceramus*, *Perna*, and *Gryphæa*, some of which are from half to three-quarters of an inch across. These large specimens present all the characters seen in sections of recent pearls as described by Dr. Herdman in his "Report to the Government of Ceylon on the Pearl Oyster Fisheries", and other works referred to. The *Inocerami* appear to have been great producers of pearls, some internal casts showing regular rows of pits between the ribs which can only be impressions of attached pearls. Most of the examples described by Mr. Newton are in the British Museum, but the finest of all, and one which shows the characteristic structure in a remarkable manner, is in the possession of Mr. B. B. Woodward. With two exceptions, all the shells showing pearl structures described in this paper are Cretaceous, and they include specimens from England, Japan, Pondoland, Germany, and the United States.

5. Silurian Bivalves of Victoria.—Sixty-two species of Silurian bivalves belonging to twenty-nine genera, including all forms known up to date, have been monographed by Mr. Frederick Chapman in the Memoirs of the National Museum, Melbourne, 1908, No. 2. These include the collections of Selwyn, McCoy, Cresswell, Spry, Jutson, and Kitson. Eleven of these are considered identical with European forms. The time has not yet arrived to zone up the series of beds from their contained fossils, as much more detailed collecting is necessary. This can only be done as more sections are made or more quarries opened in undeveloped areas. The fossils are all carefully

described, and six plates are given. Thirty-two forms are new, and the publication of this fauna in an accessible form is greatly to the credit of Mr. Chapman and the Museum authorities.

6. New Hebrides.—Chapman continues in the Proc. Linn. Soc. New South Wales for 1907 (vol. xxxii, pt. iv) his researches on the Tertiary Foraminiferal Rocks of the New Hebrides. In this paper he deals with Miocene and Post-Miocene beds from Malekula, collected by Mr. Douglas Mawson. The more important results of Chapman's work are distributional, and link up the New Hebrides with Southern Australia, the Philippines, and Japan to the north, and Java and Borneo on the west. One of the forms described, *Lepidocyclina munieri*, occurs at Vicentin in Italy. Curiously enough there is no reference to W. D. Smith's record of *Lepidocyclina* and *Lithothamnium* in the Philippines (Philippine Journ. Sci., 1907, vol. ii, No. 6, p. 396).

7. Stomach Stones.—Mr. W. H. Wickes has collected together the scattered information relative to Stomach Stones in Animals and printed it in the Proceedings of the Bristol Naturalists' Society, 1908, ser. iv, vol. ii, pt. i. He refers to the recent and fossil reptilia, fishes, mammals, and one bird (the penguin) as practising this habit, and notes that the stones are usually white and of quartz. As regards its interest to geologists, this stone-swallowing habit possibly explains the small nests of pebbles found in deposits to which they are entirely foreign, and their deposition on the death and decomposition of the fish or reptile to which they belonged is possibly quite as likely as the old theory of their being transported by floating roots or ice.

8. Colour-Markings on Fossil Mollusca.—The colour-markings preserved on fossil shells have long had a fascination for the collector, and some of these markings have been retained in a remarkable manner. Mr. R. B. Newton, in a recent paper (Proc. Malac. Soc., 1907, vol. vii, pt. v), has collected together the available material and illustrated many interesting examples. Shells showing colour-bands are known from the Silurian period to the Pleistocene, excellent specimens coming from the Carboniferous Limestone. The finest examples given by Mr. Newton are a *Naticopsis* from the Devonian and a *Mourlonia* from the Carboniferous. The fact of the colour-bands being preserved is of little or no importance geologically, but as a side issue has considerable interest.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

November 18, 1908.—Professor W. J. Sollas, LL.D., Sc.D., F.R.S., President, in the Chair.

The following communication was read:—

"On some Intrusive Rocks in the Neighbourhood of Eskdale (Cumberland)." By Arthur Richard Dwerryhouse, D.Sc., F.G.S.

There appear to be five well-marked groups of intrusions in this district—

(*a*) The andesitic dykes in the neighbourhood of Allen Crags and Angle Tarn.

(*b*) The dykes of the spherulitic and felsitic group on Yewbarrow and High Fell.

(*c*) The dioritic ('bastard granite') bosses of Peers Gill, Lingwell Crag, and Bursting Knotts, with their associated dykes.

(*d*) The Eskdale Granite, with the granite-porphyry dyke running from Great Bank to Wasdale Head and thence to Kirkfell Crags.

(*e*) The dolerite dykes, having a general north-west to south-east trend.

The dykes of series (*a*) bear a very strong petrological resemblance to the Borrowdale volcanic rocks, into which they were intruded. Furthermore, they are weathered to much the same extent and have developed the same secondary minerals, among which epidote is conspicuous. They appear to the author to be of Borrowdale age, and roughly contemporaneous with the lavas and ashes into which they are intruded. The spherulitic and more acid series (*b*) are considered to be also of Borrowdale age, though probably somewhat later than the andesitic series. The rocks of the dioritic group (*c*) are considered to be the holocrystalline and hypabyssal equivalents of the Borrowdale Lavas, and the author is of opinion that they also are of Ordovician age.

The Eskdale and Wasdale Granites (*d*) are much more acid, and show little sign of alteration except that due to weathering and dislocation. They are undoubtedly intrusive into the Borrowdale Series, but seem to be pre-Triassic. Thus the intrusion is probably Devonian, like the neighbouring granite of Shap, which, with the exception of its large phenocrysts of orthoclase, is not dissimilar to some of the varieties of the Eskdale granite. The basic intrusions (*e*) have only been examined where they come into proximity to the granite. They may well be connected with the great Tertiary basic flows of Antrim, as has been suggested by Mr. Harker.

The granite becomes progressively more and more acid as its margin is approached, until in some places the percentage of silica amounts to 96·16. This is explained by the assumption that the magma as a whole was more acid than the eutectic mixture of quartz and orthoclase, and that consequently the excess of silica separated in the marginal portions, which were the first to solidify.

December 2, 1908.—Professor W. J. Sollas, LL.D., Sc.D., F.R.S., President, in the Chair.

The President announced that a Special General Meeting would be held on Wednesday, February 10, 1909, in order to consider the result of the vote of the Fellows on the question of the Admission of Women into the Society.

The following communication was read:—

"The Geological Interpretation of the Earth-Movements associated

with the Californian Earthquake of April 18, 1906." By Richard Dixon Oldham, F.G.S.

At the time of the San Francisco earthquake movement took place along a fault, known as the San Andreas Fault, which can be traced for a distance of about 200 miles. A remeasurement of the primary triangulation in the region shaken by the earthquake revealed considerable displacement, increasing in amount as the fault is neared, and of such nature that places to the east of the fault were shifted southwards while those to the west of it were shifted northwards. The author points out that the extent and peculiar distribution of these displacements negative the supposition that the fault was the cause—it must rather be regarded as a consequence of, or an incident in, the earthquake, this word being used to denote the disturbance in its entirety.

He also considers that the displacements cannot be explained in a satisfactory manner on the supposition that they are the result of strains affecting the crust of the earth as a whole, but may be explained by the difference in character and behaviour of the materials composing the greater part of it, where pressures are great enough to produce the phenomena of solid flow, and of those in the outer skin, where the pressures are not great enough to produce any material difference in the behaviour of rocks from that which we associate with solidity, as experienced at the surface of the earth. The surface-displacements constituting the earthquake, as ordinarily understood, arise from disturbances in the outer skin; but in great earthquakes, like the one dealt with in the paper, these may be the result of more deep-seated disturbances affecting the whole crust of the earth. A distinction is drawn between these two forms of disturbance, and the term bathyseism is proposed for the deep-seated disturbance: the wave-motion which impresses itself on distant seismographs and constitutes the teleseism or world-shaking earthquake being the product of the bathyseism.

The deep-seated cause, or bathyseism, of the San Francisco earthquake is regarded as the result of a widespread strain, of the nature of a shear, such as might have been produced by displacements approximately parallel to the general direction of the coastline, and by forces which must have been very different from those concerned in the formation of the San Andreas Fault. This fault cannot, consequently, be regarded as the cause of the earthquake, nor the earthquake as an incident in the growth of the fault.

Mr. W. Whitaker called attention to specimens of impressions of salt-crystals from a local sandstone in the Keuper Marl at North Curry (Somerset). Pseudomorphs of salt-crystals were well known, but, so far as he knew, the occurrence of impressions, not filled in (and which might be taken as arrested pseudomorphs), had not been hitherto recorded in this country. The only notice of such that he knew of was from America, in 1842. Now that this occurrence was recorded, probably other examples would be noticed.

II.—Mineralogical Society.

November 17, 1908.—Professor H. A. Miers, F.R.S., President, in the Chair.

On Mica from North Wales and Chlorite from Connemara; by Messrs. A. Hutchinson and W. Campbell Smith. A mica from Tan-y-bwlch, North Wales, is found in pale-green scales in quartz veins, and approximates closely in composition to the variety of muscovite known as sericite. A chloritic mineral from Recess occurs in transparent hexagonal plates in the quarry whence the Connemara marble is obtained. It is nearly uniaxial and positive, and was found on analysis to have the composition of penninite.—On the occurrence of the rare mineral Carminite in Cornwall; by Mr. Arthur Russell. This mineral, an arsenate of iron and lead, first found at Horhausen, Rhenish Prussia, and described by F. Sandberger in 1850, was discovered in Cornwall by the author in 1906. It occurs as carmine-red or brown needles on crystallized scorodite, mimetite, etc., from Hingston Down mine. This adds one more species to the already long list of rare minerals yielded by Cornwall.—Russian Universal Instruments and Methods; by Mr. T. V. Barker. Several of the universal instruments devised and kindly lent by Professor E. Fedoroff were exhibited and the method of working explained. Among the instruments described were: the hemisphere and graduated rotatory quartz compensator of Professor V. Nikitin, the stereographic rule, circle-ruler, graduated mica and quartz compensators, universal crystal mirror-models and globes, the micro-dichroscope, and the universal microscope-stage. The great utility of the latter was demonstrated by the actual determination (using a simple projection apparatus and screen) of the optical constants, twin-law, and chemical composition of a plagioclase twin. Methods of determining birefringence and the thickness of a section were discussed, and emphasis was laid on the special usefulness of the three-legged compasses in rapid calculations by graphical methods.—On the composition of the Chandakapur Meteoric Stone: by Messrs. H. E. Clarke and H. L. Bowman. This meteorite, which fell in India in 1838, is of chondritic type, with numerous chondrules of varying structure, and consists principally of olivine and bronzite, and about 5 per cent. of nickel-iron.

CORRESPONDENCE.

THE TYGERBERG ANTICLINE.

Sir,—I recently spent a week in the country between Prince Albert village and the east end of Tygerberg in order to see the evidence for the inverted fold said to exist there by Dr. Sandberg.[1] Without troubling you with details, which will be published in the Ann. Rep. Geol. Com. of Cape Colony for 1908, may I state briefly the results of my observations, as the question of the existence of

[1] See Geol. Mag., 1908, p. 311.

the fold has been raised in your pages? There seemed to me to be no room for doubt as to the anticlinal structure of Tygerberg; as Professor Schwarz points out,[1] such a structure is clearly seen, even in the section of which a photograph is given by Dr. Sandberg in support of his views. There are many sections through the range where clear evidence of the existence of the anticline is seen, and one can walk along the axis of the anticline with the beds dipping away on either side.

I could find no trace of the Witteberg Beds *in situ* in the Sand River Valley as required on Dr. Sandberg's view, and as inserted in his sections. On the other hand, the few outcrops there are of Ecca Beds, and the character of the valley is such as to make it extremely unlikely that the Witteberg Beds ever existed there above the present surface.

The masses of quartzite in the Dwyka area belong to the Dwyka Series itself; they are lenticular beds of quartzite such as have been described from that formation in other places on the south and west sides of the Karroo.

ARTHUR W. ROGERS.

GEOLOGICAL COMMISSION,
SOUTH AFRICAN MUSEUM, CAPE TOWN.
November 17, 1908.

BURNING CLIFFS.

SIR,—I recollect the burning cliff at Holworth. As a little boy I used to ride my pony often from Osmington to visit it. The fire was in the face of a part of the cliff that had slipped so as to form a pond at the back of it. It seems that a disturbance which admits some air and water to favour decomposition is the promoting cause of these occurrences. I have picked up pebbles of baked shale and cellular slag on the beach some twenty years after all traces of the fire had disappeared from the face of the cliff at Holworth.

O. FISHER.

GRAVELEY, HUNTINGDON.
December 3, 1908.

FLINTS IN DENMARK.

SIR,—It is incredible that any Danish geologist can have intended to inform Mr. Sheppard that there was no flint in Denmark (see GEOL. MAG., December, 1908, p. 575). Visitors to Copenhagen may have observed the English Church of St. Alban at the entrance to the well-known promenade, Lang Linie. The late Sir Arthur Blomfield told me that, when he was commissioned to build this church, he had some difficulty in finding a suitable stone, till it occurred to him to enquire, "Have you no flints in your Danish Chalk?" "Plenty," was the reply. Whereupon he adopted this local stone, almost unused before in that country, and raised a building that recalls to English visitors many a familiar church of Sussex, Hampshire, and Norfolk.

F. A. BATHER.

December 2, 1908.

[1] See GEOL. MAG., 1907, "The Tygerberg Anticline," by Professor E. H. L. Schwarz, pp. 487–90, Pl. XXII; and 1908, p. 479.